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## EDITORIAL

Shortly after this issue of the *Journal* is due to be distributed, the Ninth International Astronautical Congress will be held in Amsterdam (25–30 August). On two previous occasions the interest of these Congresses has been heightened by the conjunction of other events of outstanding astronautical importance. During the Copenhagen Congress, in 1955, the existence of both the U.S. and U.S.S.R. satellite programmes was announced. As delegates to last year's Congress began to assemble in Barcelona, Sputnik I was making its first circuits around the world.

Is history to repeat itself? Is it likely that another astronautical advance will coincide with this year's Congress? For some month's there have been rumours, "leaks," and plain guesses that an American attempt to fire a lunar probe would take place between 15 and 19 August, when the Moon is nearest to the Earth. Then came the welcome establishment of a joint Anglo-American observation team at Jodrell Bank, a period of waiting and the failure of the first U.S. launching. However, a similar Russian programme (no doubt intended to be even bigger and better) also exists and another U.S. attempt is expected shortly.

The exact date on which the first lunar probe is launched is of little importance. And to be frank, if we leave aside the military and political implications which are unfortunately associated with the launching vehicles, it does not matter much to Britain and the rest of the world whether the first lunar probe (or the first lunar landing) is American or Russian. What is important if we ourselves cannot participate is that some representative of *homo sapiens* should make a lunar landing—and go on from there.

Those may be one's first thoughts, but we too, must go on from there. Is space travel to be one more of the natural means of selection (a topical thought in Darwin and Wallace's centenary year)? Are only Americans and Russians fit to cross space? That is the picture at present; it could be changed if either other nations began (acting alone or in consort) to set up their own astronautical programmes, or the present participants invited international participation in their own work.

# SATELLITE ORBITS IN THEORY AND PRACTICE*

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(Communication from The Royal Aircraft Establishment)

SUMMARY

This paper deals with three main topics. First, the chief features of the orbits of Earth satellites are discussed, taking into account the effects of the Earth's oblateness and atmosphere. Then the method of determining the orbit from kinetheodolite and theodolite observations is described; and finally a comparison is made between theory and observation, for Sputnik 2.

## General Features of Satellite Orbits

It would be a great deal easier to compute satellite orbits if the Earth were perfectly spherical and had no atmosphere; for then the satellite could be assumed, for most practical purposes, to move in a simple elliptic orbit in a plane whose direction is fixed relative to the stars. The real Earth is not a perfect sphere however and its atmosphere, though tenuous, was still appreciable at the heights where the first two Sputniks disported themselves. The two main perturbations to the orbit are those caused by the Earth's oblateness and its atmosphere, and these perturbations will be described in more detail later in this paper.

But first it would be as well to mention the other smaller perturbations which have so far been ignored in determining the orbit. First, there are electromagnetic effects caused by the satellite's motion through the Earth's magnetic field: these may well influence the attitude of the satellite, though they probably have a negligible effect on its orbit. Second, it is probable that the Earth, as well as being oblate, is not exactly symmetrical either about its axis or about the equatorial plane; but it is expected that these effects will also be negligible. Third, there are relativity effects. If Einstein's law of gravitation were used instead of Newton's, there would be a rotation of the major axis of the orbit, at a rate of about 0·005 degrees per year. This is negligible, since the major axis may rotate as much as a million times faster as a result of the Earth's oblateness. Fourth, there are the gravitational attractions of the Sun, Moon and planets. Spitzer[1] has shown that the attractions of the Sun and Moon alter the radial distance of the satellite by about 1 foot and 2 feet respectively, and rotate the plane of the orbit at rates of about 0·05 and 0·1 degrees per year. These perturbations are, with present accuracies, just small enough to ignore, since the effects of oblateness are about 30,000 times greater. The total influence of the planets is at most one five-thousandth that of the Sun, over 80 per cent. of this small amount being contributed by Venus at inferior conjunction.

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By a fortunate chance the two main sources of perturbation to the orbit, the Earth's oblateness and its atmosphere, give rise to perturbations of quite different types, and so they can with a high degree of accuracy be treated and described separately.

**Effect of the Earth's Oblateness**

The gravitational potential $U$ outside a non-uniform oblate Earth may, assuming symmetry about the equatorial plane, be written in the form

$$U = gR\left\{\frac{R}{r} + J\frac{R^3}{r^3}\left(\frac{1}{3} - \cos^2\theta\right) + \frac{D}{35}\frac{R^5}{r^5}(35\cos^4\theta - 30\cos^2\theta + 3) + \ldots\right\} \quad (1)$$

where $R$ is the Earth's equatorial radius (3441·69 nautical miles),

$r$ is the distance from the Earth's centre,

$\theta$ is the angle between the Earth's axis and the radius vector,

$J$ and $D$ are constants, which, following Jeffreys,[2] we take as

$$J = 1{\cdot}637 \times 10^{-3} \text{ and } D = 10{\cdot}6 \times 10^{-6}.$$

The constant $g$ is chosen so that the acceleration due to gravity at the equator as given by (1), namely $g(1 + J + 3D/7)$ is equal to the sum of the observed apparent gravity at the equator and the correction for the Earth's rotation. This gives $g = 32{\cdot}146$ ft./sec.$^2$.

The orbit of a satellite *in vacuo* over an oblate Earth differs in three ways from the orbit over a spherical Earth. First, the plane of the orbit is no longer fixed in direction but rotates about the Earth's axis in the direction opposite to the satellite's motion, while still remaining inclined at a fixed angle to the equator. Although the satellite therefore does not really move in a plane it is still convenient to imagine it lying in an "instantaneous orbital plane" and then to specify the rate of rotation of that plane about the Earth's axis. For orbits of small eccentricity $e$ the mean rate of rotation is found[3] to be

$$\sqrt{\frac{g}{R}}\left(\frac{R}{\bar{r}}\right)^2\left(\frac{R}{a}\right)^{1\cdot5}\cos\alpha\left[J + \frac{J^2R^2}{\bar{r}^2}\left(\frac{19}{12}\sin^2\alpha - 1\right) - \right.$$
$$\left. - \frac{3DR^2}{14\bar{r}^2}(7\sin^2\alpha - 4) + O(J^2e)\right] \quad \ldots \quad (2)$$

where $\bar{r}$ is the (harmonic) mean distance of the satellite from the Earth's centre, $a$ is the semi-major axis of the orbit, equal to $\bar{r}/(1 - e^2)$, and $\alpha$ is the inclination of the orbital plane to the equator (the exact definition of $\alpha$ in a perturbed orbit is disputable,[16,17] and the particular choice influences the coefficient of $J^2$ in (2)). The $J^2$ and $D$ terms in (2) are themselves small, and for many purposes the main term in (2) is adequate. Inserting numerical values for $J$, $g$, and $R$, and ignoring terms of $O(e^2)$ we find the rate of rotation given by the main term to be

$$10{\cdot}00\left(\frac{R}{\bar{r}}\right)^{3\cdot5}\cos\alpha \quad \text{degrees per day} \quad \ldots \quad \ldots \quad (3)$$

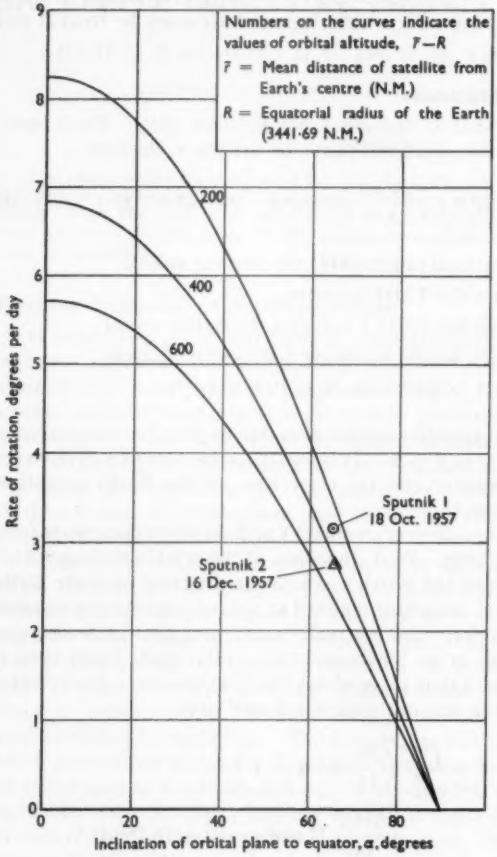


FIG. 1 (*at left*). Rate of rotation of the orbital plane about the Earth's axis.

This quantity is plotted in Fig. 1, for three values of "orbital altitude," $\bar{r} - R$. The observed values of the rate of rotation for Sputniks 1 and 2 are indicated approximately: a more detailed comparison of theory and observation is made later in this paper.

The second main effect of the Earth's oblateness is that the major axis of the orbit rotates slowly in the orbital plane, so that the orbit is a near-ellipse with a rotating major axis. The mean rate of rotation of the major axis is found[3] to be

$$J\sqrt{\frac{\bar{g}}{R}}\left(\frac{R}{\bar{r}}\right)^2\left(\frac{R}{a}\right)^{1\cdot5}\left\{\frac{5\cos^2\alpha-1}{2}+O(J)\right\} \quad .. \quad .. \quad (4)$$

For many purposes the term $O(J)$, which is about 0·002, may be ignored. If we also neglect terms of $O(e^2)$ the rate of rotation of the major axis is

$$5\cdot00\left(\frac{R}{\bar{r}}\right)^{3\cdot5}(5\cos^2\alpha-1) \quad \text{degrees per day} \quad .. \quad .. \quad (5)$$

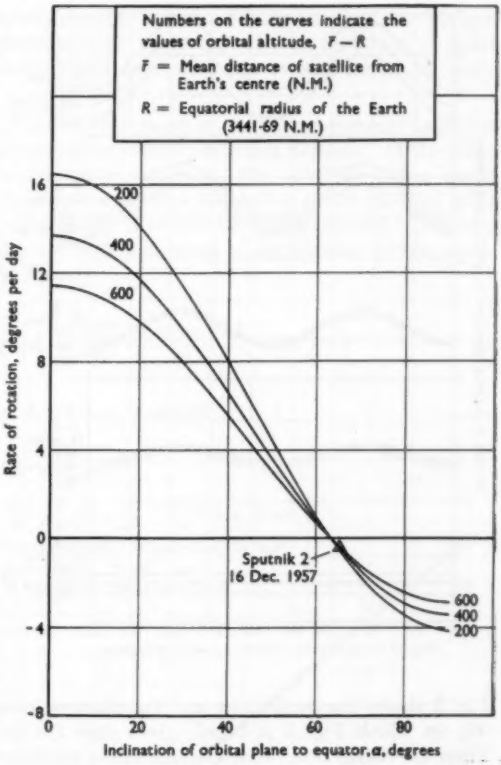


FIG. 2 (*at right*). Rate of rotation of major axis of orbit, measured in the orbital plane.

This quantity is plotted in Fig. 2, for three values of orbital altitude. It will be seen from Fig. 2 that the major axis rotates in the same direction as the satellite is moving if $\alpha < 63{\cdot}4°$, or in the opposite direction if $\alpha > 63{\cdot}4°$. For Sputniks 1 and 2, with $\alpha \simeq 65°$, the rate of rotation was therefore quite slow—and this was a great help in establishing their orbits.

The third perturbation caused by the Earth's oblateness is a change in radial distance $r$ of the satellite from the Earth's centre, indicating the amount by which the orbit departs from an ellipse. For a given value of $\alpha$ the increase in $r$ is found[3] to be

$$-\frac{JR^2}{6r}\sin^2\alpha\cos 2\psi = -0{\cdot}94\frac{R}{\bar{r}}\sin^2\alpha\cos 2\psi \text{ n. miles} \quad .. \quad (6)$$

where $\psi$ is the angular travel of the satellite in the orbital plane, measured from the apex or point of maximum latitude. This perturbation is therefore an oscillation in $r$, of amplitude $0{\cdot}94\ (R/\bar{r})\sin^2\alpha$ n. miles, and period half the period of revolution of the satellite. $r$ is smaller than on the unperturbed orbit when the satellite is near apex and greater when it is near the equator. Because of the Earth's oblateness there is also a change in the mean distance of the satellite from the Earth's centre as $\alpha$ varies, when the angular momentum is kept constant. This increase in mean distance is

$$-\frac{JR^2}{2\bar{r}}(5\cos^2\alpha - 3) = -2{\cdot}82\frac{R}{\bar{r}}(5\cos^2\alpha - 3) \text{ n. miles} \quad .. \quad (7)$$

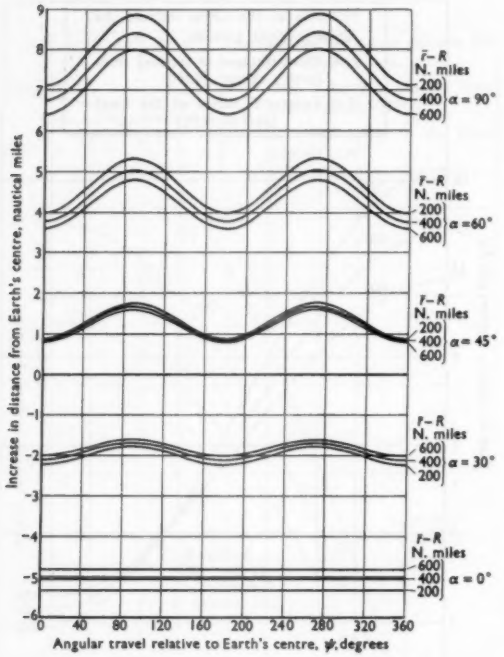


FIG. 3. Change in radial distance from the Earth's centre caused by Earth's oblateness, as given by second-order solution.

$\alpha$ = inclination of orbital plane to equator.

$R$ = equatorial radius of Earth (3441·69 N. miles).

$r$ = mean distance of satellite from Earth's centre.

Fig. 3 shows the oscillations and the changes in mean value. The expression (6), on which Fig. 3 is based, gives only the first-order perturbations in $r$. There are higher order terms, which are of amplitude 200 ft. if $e$ is of order 0·05. The fuller solution can be expressed in the form[2]

$$\frac{1}{Lr} = 1 + e\cos(\psi-\beta) + JL^2R^2\left(\frac{5\cos^2\alpha-3}{2}+\frac{\sin^2\alpha}{6}\cos 2\psi\right)+$$

$$+ Je\,\frac{5L^2R^2}{24}\sin^2\alpha\cos(3\psi-\beta) + J^2L^4R^4\left\{2-10\sin^2\alpha+\right.$$

$$\left.+\frac{97}{8}\sin^4\alpha-(4+7\sin^2\alpha)\frac{\sin^2\alpha}{18}\cos 2\psi+\frac{\sin^4\alpha}{24}\cos 4\psi\right\}+$$

$$+ DL^4R^4\left\{\frac{3}{7}-3\sin^2\alpha+\frac{25}{8}\sin^4\alpha-\left(\sin^2\alpha-\frac{6}{7}\right)\frac{\sin^2\alpha}{2}\cos 2\psi-\right.$$

$$\left.-\frac{\sin^4\alpha}{40}\cos 4\psi\right\}+O(Je^2) \quad .. \quad .. \quad .. \quad .. \quad .. \quad (8)$$

where $L$ is a constant very nearly equal to $\bar{r}^{-1}$, and $\beta$ is the value of $\psi$ at perigee. The third term on the right-hand side represents the perturbation of order one mile, and the next three terms represent the perturbations of order 200 ft.

One other effect of the Earth's oblateness is worth mentioning: satellites with different orbital inclinations have slightly different periods. If the mean distance from the Earth's centre, $\bar{r}$, is fixed, the satellite takes about $14{\cdot}5(R/\bar{r})^{\frac{1}{2}} \sin^2 \alpha$ seconds longer to complete a revolution on an inclined orbit than on an equatorial one. The period of revolution of the satellite, $T$, defined as the nodal period (from one northward crossing of the equator to the next), can best be expressed[3] in the form

$$T = 2\pi\sqrt{\frac{a^3}{gR^2}}\left\{1 - \frac{JR^2}{\bar{r}^2}\,\frac{7\cos^2\alpha - 1}{4} + O(J^2)\right\} \qquad .. \qquad (9)$$

$T$ is plotted against $a$ in Fig. 4, for $\alpha = 0$ and 90°.

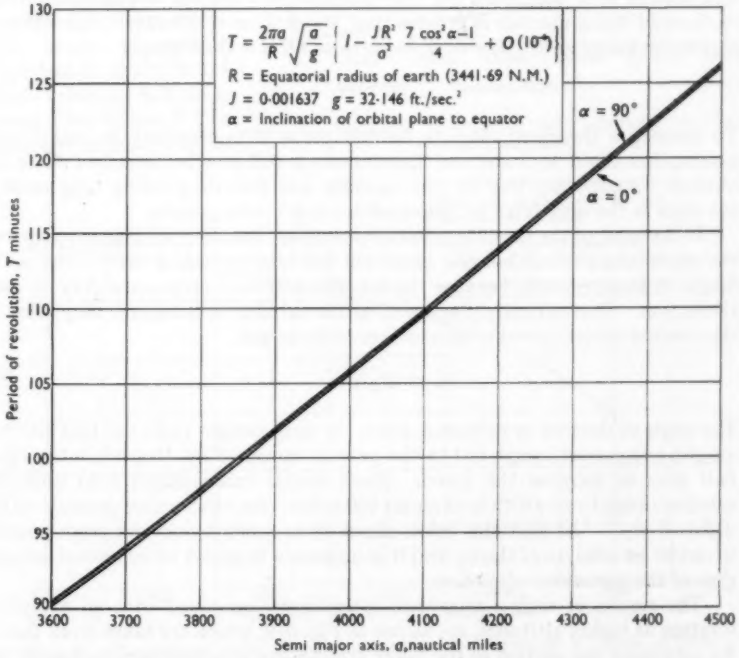


FIG. 4. Semi-major axis of satellite orbit *versus* period of revolution.

**Effect of the Atmosphere**

The effect of the atmosphere on a satellite orbit is very different from the effect of the Earth's oblateness, because the air drag is constantly whittling away the energy of the satellite and in the end brings it down to Earth. As a result of the oblateness, as we have seen, the plane of the orbit rotates, the major axis rotates, and the ellipse is slightly distorted, but without much change in eccentricity or period of revolution. The effect of the atmosphere on the other hand is to reduce the length of the major axis, but without rotating it, to reduce the eccentricity and to reduce the period, all at ever increasing rates.

The drag $D$ acting on a body moving with velocity $v$ in a medium of density $\rho$ is usually expressed in the form

$$D = \frac{1}{2}\rho v^2 SC_D \qquad .. \quad .. \quad .. \quad .. \qquad (10)$$

where $S$ is a reference area, taken as the cross-sectional area perpendicular to the flow, and $C_D$ is the non-dimensional drag coefficient. For satellites at altitudes of over 100 miles the free-molecule flow régime applies, and if the isothermal Mach number is greater than about 5, as it usually is, the value of $C_D$ can be taken as 2. The drag/mass ratio $D/m$ is then simply

$$\rho v^2 S/m \qquad .. \quad .. \quad .. \quad .. \qquad (11)$$

To develop a theory of satellite descent paths it is necessary to make some assumption about $m/S$ and the theories which will now be described make the obvious assumptions, that $m/S$ is constant and that drag acting tangential to the path is the only force on the satellite, apart from gravity.

If the orbit of the satellite is initially circular, the effect of drag is to convert the circle into a spiral, but the spiral will still be very near a circle if the initial height is large enough, because the satellite will only drop a few feet on each revolution. Consequently the speed of the satellite will remain very close to the circular orbital speed $v_c$ appropriate to its height,

$$v_c = \sqrt{gR^2/r} \qquad .. \quad .. \quad .. \quad .. \qquad (12)$$

The angle of descent in radians is twice the drag/weight ratio,[4] so that half the weight component tangential to the path is cancelled by drag while the other half goes to increase the speed. These simple relationships hold until the satellite drops to an altitude of about 100 miles—the exact value depends on the value of $m/S$. At altitudes below about 40 n. miles it does not seem possible to devise an analytical theory and it is necessary to resort to numerical integration of the equations of motion.

The results of such a numerical integration, combined with an analytical solution at higher altitudes, are shown in Fig. 5–9, which are taken from Ref. 5. To determine the motion in the lower atmosphere it is necessary to specify the shape of the satellite as well as the value of $m/S$. In the example illustrated

in Fig. 5–9 the "standard satellite" was arbitrarily taken as a cone with a mass of 2,000 lb., a base area of 20 ft.$^2$ and an apex angle of 15°; and it was assumed that it remained pointing nose forward at zero angle of incidence, and undamaged by heating. The variation of velocity with altitude is shown in Fig. 5, on the assumption that the change-over from free-molecule to continuum flow occurs at 40 n. miles altitude, and the broken line shows what happens if this change-over point is shifted to 50 n. miles. The height of change-over has no effect on the final velocity, which is about 700 ft./sec. The standard atmosphere of

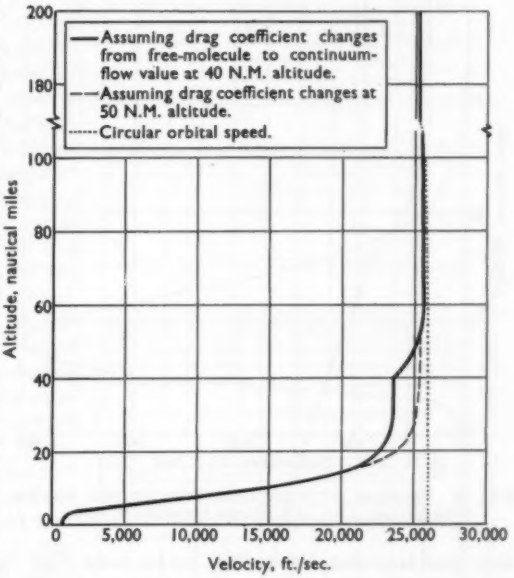


FIG. 5. Variation of velocity with altitude for the standard satellite.

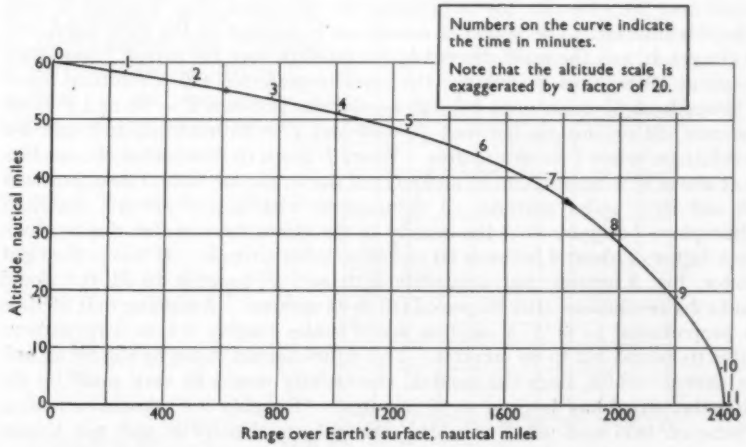


FIG. 6. The descent path of the standard satellite, from 60 N. miles altitude downwards.

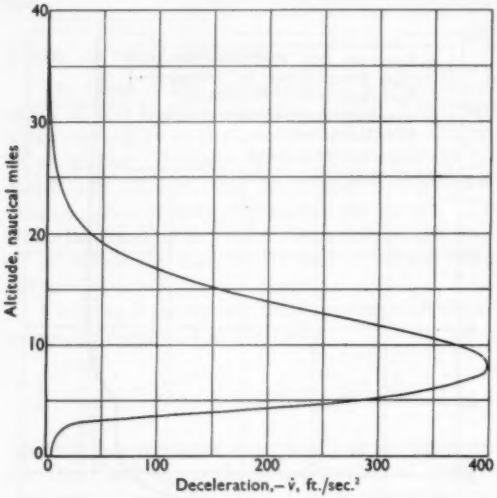


FIG. 7. Variation of deceleration with altitude, for the standard satellite, at altitudes below 40 N. miles.

Ref. 6 was used in the calculations. The descent path from 60 n. miles downwards, is shown in Fig. 6, the deceleration in Fig. 7, and the angle of descent in Fig. 8.

The complete descent path from 200 n. miles altitude is summarized in Fig. 9, in which the number of revolutions is plotted against height, with time in days marked on the curve. Since the standard atmosphere of Ref. 6, like all pre-Sputnik atmospheric models, is likely to be considerably in error, the numerical values of Fig. 9 would apply not for the value of $m/S$ for which they were intended, 100 lb./ft.$^2$, but for some other value of $m/S$, differing from 100 lb./ft.$^2$ by the same factor by which the density in the assumed atmosphere differs from the true density. This factor is thought to be about 3, for altitudes between 100 and 150 n. miles, so Fig. 9 may apply for a value of $m/S$ somewhere near 30. Despite the uncertainty on this point, Fig. 9 is still of considerable interest. The period of revolution is marked on the right-hand side of the graph, and the rapid descent of the satellite once the period $T$ has fallen to about 89 minutes is striking: the satellite performs 420 revolutions while $T$ drops from 91 minutes to 90; 120 revolutions between $T = 90$ and $T = 89$ minutes; 22 revolutions between $T = 89$ and $T = 88$ minutes; and only 2·4 revolutions below $T = 88$ minutes. When $T$ drops to 88 minutes the satellite is at about 90 n. miles altitude, and most of the remaining time is spent between 90 and 60 n. miles altitude. A comparison with a post-Sputnik standard atmosphere [9] suggests that the density in the atmosphere of Ref. 6 is too high by a factor of about 4 between 60 and 90 n. miles altitude. If this is the right factor, Fig. 9 implies that a satellite with $m/S$ of roughly 25 lb./ft.$^2$ would make 2·4 revolutions after its period fell to 88 minutes. Assuming that lifetime is proportional to $m/S$, a satellite would make roughly 0·1 $m/S$ revolutions after its period fell to 88 minutes. This figure should apply to elliptic as well as circular orbits, since the residual eccentricity would be very small by the time the period has dropped to 88 minutes. "Roughly 0·1" should be read as "between 0·05 and 0·2," since the atmospheric density is still not known accurately at these altitudes.

The effects so far described apply primarily to circular orbits. When

the orbit is an ellipse of appreciable eccentricity ($> 0{\cdot}02$ say) the process of descent is at first rather different. Almost all of the retardation due to drag occurs at or very near perigee, and consequently there is a reduction in height at the subsequent apogee, but very little change in perigee height. So the orbit becomes more nearly circular and the period decreases because the average height is being reduced. The effect of air drag on elliptic satellite orbits has been studied by a number of authors, including Henry,[7] Okhotsimskiĭ, Eneev and Taratynova,[8] Fejer,[10] Scott,[11] Leslie,[12,16] Roberson,[13] Nonweiler,[14] Parkyn[15] and Groves.[19] In these papers it is assumed that $SC_D/m$ is constant, and that the atmospheric density $\rho$ is constant from day to day, and varies exponentially with altitude, so that $\rho \propto \exp(-r/H)$, where $H$ is a constant, the "scale height." By an extension of the analyses in these papers the following useful results can be derived.[20]

First, if the eccentricity is neither too large nor too small,

$$\frac{T}{T_0} = 1 - \frac{3}{2}e_0\left(1 - \frac{5}{3}e_0\right) \times$$

$$\times\left(1 - \sqrt{1 - \frac{t}{t_L}}\right) - \frac{17}{8}e_0^2\frac{t}{t_L} +$$

$$+ \frac{3H}{8a_0}\ln\left(1 - \frac{t}{t_L}\right) +$$

$$+ O(e_0^3) + O\left(\frac{H^2}{a^2}\right) \quad .. \quad (13)$$

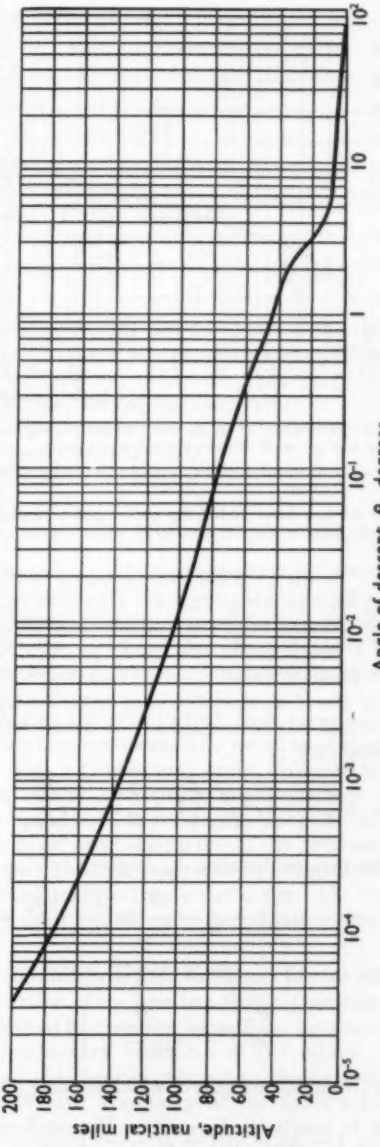


FIG. 8. Variation of angle of descent with altitude for the standard satellite.

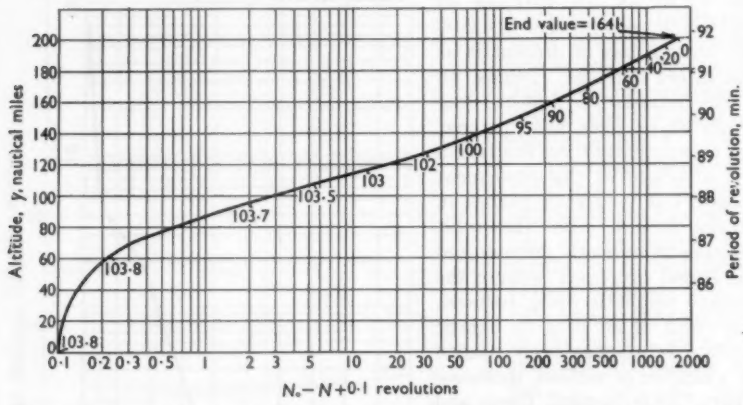


FIG. 9. The number of revolutions remaining to be performed by the standard satellite when at any given altitude on its descent path.

$N_0 - N$ = number of revolutions made by satellite in dropping from altitude $y$ to sea level.

The 0·1 has been added for convenience in plotting. Numbers on the curve indicate the time in days from 200 N. miles altitude.

where $T$ is the period of revolution, $t$ is time, $a$ is the semi-major axis, and suffix $_0$ denotes initial values. $t_L$ may be called the total lifetime, though it is slightly greater than the real lifetime because it corresponds to the time at which $T$ drops not to the lowest practical value (say 87 minutes), but to the lowest possible value, $-\infty$. Equation (13) will not apply if either the $e_0^2$ term or the $H/a_0$ term becomes large, for then the $O(e_0^3)$ term or the $O(H^2/a^2)$ term would not be negligible. A useful formula for lifetime, found by differentiating (13), is

$$t_L = \frac{3}{4}\frac{e_0 T_0}{(-dT/dt)_0}\left\{1 + \frac{7}{6}e_0 + \frac{H}{2a_0 e_0} + O(e_0^2) + O\left(\frac{H^2}{a^2 e_0^2}\right)\right\} \quad .. \quad (14)$$

The perigee distance, $r_p$, is given by

$$r_p = a_0\left\{1 - e_0 - \frac{H}{2a_0}\ln\frac{(1+e)e_0}{(1+e_0)e} + O(e_0^3) + O\left(\frac{H^2}{a^2}\right)\right\} \quad .. \quad (15)$$

and the rate of change of perigee distance is

$$\frac{dr_p}{dt} = -\frac{H}{4(t_L - t)}\left\{1 + O(e_0) + O\left(\frac{H}{a}\right)\right\} \quad .. \quad .. \quad (16)$$

From (15) it follows that $a$, which equals $r_p/(1-e)$, is given by

$$\frac{a}{a_0} = 1 - (e_0 - e)(1+e) - \frac{H}{2a_0}\ln\frac{e_0(1+e)}{e(1+e_0)} + O(e_0^3) + O\left(\frac{H^2}{a^2}\right) \quad .. \quad (17)$$

The eccentricity can be expressed in terms of $t$ as

$$\frac{e}{e_0} = \sqrt{1 - \frac{t}{t_L}}\left[1 - \frac{e_0}{6}\left(1 - \sqrt{1 - \frac{t}{t_L}}\right) + \right.$$
$$\left. + O\left\{\frac{H}{a}\ln\left(1 - \frac{t}{t_L}\right)\right\} + O(e_0^2)\right] \quad .. \quad .. \quad .. \quad (18)$$

Equation (18) shows incidentally that if the terms in $e_0$ and $H/a_0$ are small, the variation of $e^2$ with $t$ is nearly linear. Finally, from (15),

$$\frac{T}{T_0} = \left(\frac{1 - e_0}{1 - e}\right)^{\frac{3}{2}}\left\{1 - \frac{3H}{4a_0}\ln\frac{(1 + e)e_0}{(1 + e_0)e} + O\left(\frac{H^2}{a^2}\right) + O\left(\frac{H}{a}e\right)\right\}$$

More accurate forms of equations (13)–(18) can be obtained, in terms of Bessel functions,[20] and allowance can be made for the oblateness of the atmosphere.[15,19] But the equations given here will suffice for most purposes, and sometimes it is found that the simpler forms, ignoring terms of $O(e^2)$ and $O(H/a)$, yield results which fit the observations just as well. The variation of period with time, as given by the simpler form of (13),

$$\frac{T}{T_0} = 1 - \frac{3}{2}e_0\left(1 - \sqrt{1 - \frac{t}{t_L}}\right) \quad .. \quad .. \quad .. \quad (19)$$

is plotted in Fig. 10 for various values of $e_0$. The right-hand ends of the curves correspond to the points where the eccentricity has fallen almost to zero: from then onwards the satellite is, effectively, in a circular orbit, and the lifetime in the "circular final phase" will be very short, so that the end-points of the curves in Fig. 10 will usually correspond very nearly to the end of the satellite's life.

The theories of the effect of drag on the orbit, which have been described above, give no indication that the atmosphere causes any rotation of the plane of the orbit or of the major axis. Such rotations may occur, however, though at very slow rates. The rotation of the atmosphere might produce a net lateral force on the satellite which would tend to rotate the plane of the orbit (and it is of interest that an exactly polar orbit should reveal any such rotation directly). Also, asymmetries between the drag approaching perigee and the drag on departing from perigee would tend to rotate the major axis, though this is a small effect which is not revealed by first-order perturbation theory.

**Digital Computer Analysis of Satellite Observations**

A large number of visual observations of the first two Russian satellites has been analysed by manual methods and the results have been invaluable in preparing prediction charts and preliminary estimates of the orbital parameters. In order to check in detail the theories relating to the various perturbation effects, and also to improve our knowledge of the Earth's atmosphere and gravitational field, it is necessary to have observations of much greater accuracy. As a first step in this direction a series of kinetheodolite

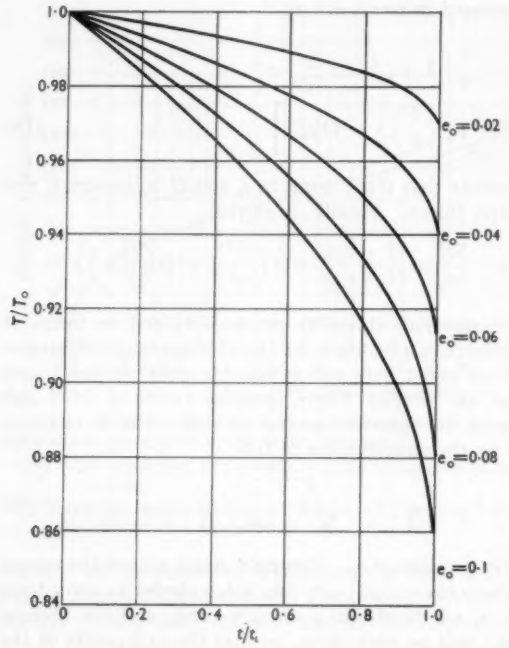


FIG. 10. Variation of orbital period with time as given by Equation (19).

observations of the second Russian satellite has been made from Ministry of Supply stations at Aberporth, Bramshot, Larkhill, Orfordness and West Freugh. From each film record obtained a table of elevation and azimuth angles against G.M.T. is prepared and these form the raw data for subsequent analysis. It has been found that the accuracy of the angular data is of the order of 20 seconds of arc and that of the timing about 20 milliseconds.

In addition to the kinetheodolite observations, one sequence of theodolite observations from Woomera (South Australia) and several from Jokioinen (Finland) have been analysed. These are not as accurate as the kine observations but are useful in that they lie outside the narrow band of latitudes covered by the kine stations.

The determination of the satellite orbit from these observations involves an extended computation, and in order to do this in a reasonable time use has been made of the Pegasus digital computer at the Royal Aircraft Establishment. Two programmes have been prepared for the computer, the first programme providing for an analysis of observations of one transit from a single station and the second programme dealing with simultaneous observations from two stations. Little use has been made of the second programme as the quantity of simultaneous data has been extremely meagre.

The "single station" programme was originally written for use with radio interferometer data in the form of direction cosines $m$, $n$ between the sight-line and the E–W and N–S axes in the horizontal plane of the observing station. Thus, a preliminary programme is used to convert the elevation and azimuth angles obtained from the kinetheodolites to direction cosines; at the same time a refraction correction is applied to the observed elevation angles.

The motion of an Earth satellite may be represented by six orbital elements or by any six independent functions of these.

For the present purpose the six parameters chosen are:

$T$, the orbital (nodal) period,

$r_p$, the radius vector at perigee,

$\alpha$, the inclination of the orbital plane to the equatorial plane of the Earth,

$h_0$, the height,

$\lambda$, the longitude relative to the observing station, and

$\tau$, the time;

$h_0$, $\lambda$ and $\tau$ referring to the instant the satellite crosses the latitude of the observing station.

When the observation is not too close to the perigee, these six quantities determine the orbit, apart from minor ambiguities which are easily resolved. If the observation is close to perigee, the height and the perigee radius vector coalesce and the precise position of the perigee is indeterminate.

It will be obvious that it is not possible to estimate all six parameters from observations made at one station during one transit of the satellite. If, however, $T$ and $r_p$ may be assumed to be known then it is possible to estimate the other four, and this is, in fact, the basis on which the computer programme was designed. The orbital period $T$ is known to four significant figures from visual observations, and the main difficulty is in determining sufficiently accurate values of $r_p$. For the second Russian satellite the perigee lay in English latitudes during the early part of November, 1957, so that a direct measurement of $r_p$ could be made. Since then the perigee has moved slowly southwards and indirect methods, combined with the use of theoretical equation (16), have provided estimates of $r_p$.

At any given time $t$ during an observation period the direction cosines $m$, $n$ of the satellite relative to the observing station may be written as functions of the six parameters $T$, $r_p$, $\alpha$, $h_0$, $\lambda$, $\tau$ and the time $t$, that is

$$m \equiv m(T, r_p, \alpha, h_0, \lambda, \tau, t)$$
$$n \equiv n(T, r_p, \alpha, h_0, \lambda, \tau, t).$$

The inner loop of the Pegasus programme takes the assumed values of $T$ and $r_p$ together with first guesses at the values of $\alpha$, $h_0$, $\lambda$ and $\tau$ and computes $m$ and $n$ for the sequence of values of $t$ to which the observations refer. These computed values of the direction cosines are then compared with the observed values and adjustments made in the four unknown parameters in order to minimize the mean square error. The adjustments are made by the process of differential correction, which is an extension of the Gauss-Seidel iterative process to non-linear equations. The functional relationships will now be determined in more detail.

**Derivation of the Functional Expressions for $m$ and $n$**

For the purpose of analysing a sequence of observations over a small interval of time, say 3 minutes, it is sufficient at first to assume that the plane of the

satellite orbit remains fixed in direction, and the notation, shown in Fig. 11, makes use of this.

Take right-handed axes $Oxyz$ fixed in direction, with origin $O$ at the Earth's centre: $Oz$ is along the Earth's axis northwards; $Ox$ is along the line in which the orbital plane cuts the Earth's equatorial plane, taken from $O$ towards the point where the satellite crosses the equator going north. Let $A$ be the point where the orbit cuts the plane $Oyz$; let $S$ be the position of the satellite and let $\widehat{ACS} = \psi$. Then the direction cosines between $OS$ and the axes $Oxyz$ are

$$-\sin\psi,\ \cos\alpha\cos\psi \text{ and } \sin\alpha\cos\psi,$$

where $\alpha$ is the inclination of the orbital plane to the Earth's equatorial plane.

Let $(r\ \theta, \phi)$ be the spherical polar co-ordinates of the satellite and let suffix 0 refer to conditions at the instant the satellite crosses the latitude of the observing station.

Let $K$ be the position of the observing station (Fig. 12), with co-latitude $\theta_0$ (geocentric) and longitudinal angle $\eta$ measured eastwards from $Ox$. Take a new set of axes $Ox'y'z'$ with $Ox'$ in the direction of $K$ and $Oz'$ perpendicular to $Ox'$ and lying in the meridional plane through $K$. Let $l'$, $m'$, $n'$, be the direction cosines between $OS$ and the axes $Ox'y'z'$. Then

$$\begin{bmatrix} l' \\ m' \\ n' \end{bmatrix} = \begin{bmatrix} \sin\theta_0 & 0 & \cos\theta_0 \\ 0 & 1 & 0 \\ -\cos\theta_0 & 0 & \sin\theta_0 \end{bmatrix} \begin{bmatrix} \cos\eta & \sin\eta & 0 \\ -\sin\eta & \cos\eta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} -\sin\psi \\ \cos\alpha\cos\psi \\ \sin\alpha\cos\psi \end{bmatrix}$$

that is,

$$\left.\begin{aligned} l' &= -\sin\theta_0\cos\eta\sin\psi + \sin\theta_0\sin\eta\cos\alpha\cos\psi + \cos\theta_0\sin\alpha\cos\psi \\ m' &= \sin\eta\sin\psi + \cos\eta\cos\alpha\cos\psi \\ n' &= \cos\theta_0\cos\eta\sin\psi - \cos\theta_0\sin\eta\cos\alpha\cos\psi + \sin\theta_0\sin\alpha\cos\psi \end{aligned}\right\} \quad (20)$$

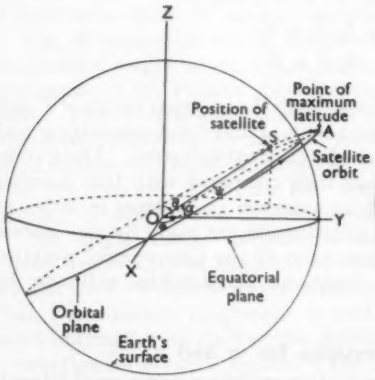


FIG. 11. Notation for satellite.

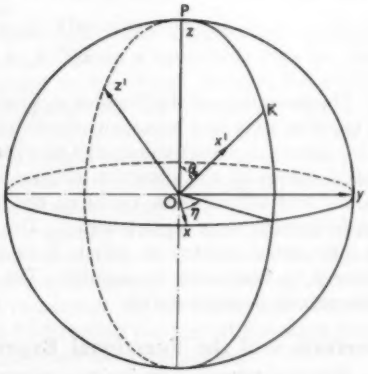


FIG. 12. Notation for observing station.

Now the axes in which the measurements are made are obtained by transferring the axes $Ox'y'z'$ without rotation to the point $K$ as origin and then performing a rotation of $\epsilon$ negatively about $Ky'$, where $\epsilon$ is the angle between the geographic and geocentric latitudes of $K$.

If $l$, $m$, $n$ are the direction cosines between $KS$ and the new axes, it is found that

$$\left.\begin{aligned} Sl &= rn' \sin\epsilon + (rl' - R_k)\cos\epsilon \\ Sm &= rm' \\ Sn &= rn' \cos\epsilon - (rl' - R_k)\sin\epsilon \end{aligned}\right\} \quad .. \quad .. \quad .. \quad (21)$$

where $S$ is the slant distance $KS$, and $R_k$ is the distance of the observing station $K$ from the centre of the Earth.

Squaring and adding these three equations, and noting that

$$l^2 + m^2 + n^2 = l'^2 + m'^2 + n'^2 = 1,$$

then
$$S^2 = h^2 + 2rR_k(1 - l'), \quad .. \quad .. \quad .. \quad (22)$$

where
$$h = r - R_k \quad .. \quad .. \quad .. \quad .. \quad .. \quad (23)$$

$h$ is called the height of the satellite.

Through equations (20) to (23) the direction cosines $m$ and $n$ are related to the co-ordinates $h$, $\eta$ and $\psi$. Now $\eta$ is the longitude of the observing station at time $t$ relative to the original axis $Ox$. Hence, the longitude of the observing station at time $\tau$ is $\eta - \omega(t - \tau)$, where $\omega$ is the angular velocity of the Earth about its axis. But this is also $\phi_0 - \lambda$, for $\phi_0$ is the longitude of the satellite at time $\tau$ relative to $Ox$, and $\lambda$ is the longitude of the satellite at time $\tau$ relative to the observing station. Hence

$$\eta = \phi_0 - \lambda + \omega(t - \tau) \quad .. \quad .. \quad .. \quad .. \quad (24)$$

$\phi_0$ depends on the orbital inclination and the latitude $\theta_0$, and from the spherical trigonometry of Fig. 11 it follows that

$$\cos\phi_0 = -\sin\psi_0 \operatorname{cosec}\theta_0 \quad .. \quad .. \quad .. \quad (25)$$

where
$$\cos\psi_0 = \cos\theta_0 \operatorname{cosec}\alpha \quad .. \quad .. \quad .. \quad (26)$$

These equations do not give an unambiguous value of $\phi_0$, and the computer has to be told which value to take, depending on whether the observing station is in the northern or southern hemisphere, and whether the transit is north-going or south-going.

In order to relate $h$ and $\psi$ to the orbital parameters it is assumed that Taylor expansions up to the second order about the transit point are adequate, that is

$$h = h_0 + \dot{h}_0(t - \tau) + \frac{1}{2}\ddot{h}_0(t - \tau)^2 \quad .. \quad .. \quad .. \quad (27)$$

and
$$\psi = \psi_0 + \dot{\psi}_0(t - \tau) + \frac{1}{2}\ddot{\psi}_0(t - \tau)^2 \quad .. \quad .. \quad .. \quad (28)$$

$h_0$ is one of the unknown parameters and $\psi_0$ is determined from equation (26). The four derivatives are determined from the elementary properties of orbits.

$$\dot{\psi}_0 = H/r_0^2$$

$$\dot{h}_0 = H\, e \sin(\psi_0 - \beta)/\bar{r}$$

$$\ddot{\psi}_0 = -2\dot{\psi}_0\dot{h}_0/r_0$$

$$\ddot{h}_0 = H\, e \cos(\psi_0 - \beta).\dot{\psi}_0/\bar{r},$$

where $H = (gR^2\bar{r})^{\frac{1}{2}}$

$\bar{r} = r_p(1 + e)$ is the harmonic mean radius vector,

$e = 1 - \dfrac{r_p}{a}$ is the eccentricity,

$a = (gR^2T^2/4\pi^2)^{\frac{1}{3}}$ is the semi-major axis,

$$\cos(\psi_0 - \beta) = (\bar{r} - r_0)/er_0,$$

$\beta$ being the angle from apex to perigee.

The computer has to be told which of the two possible values of $\psi_0 - \beta$ to take in the final expression here.

In the currently used programme certain first order corrections for Earth's oblateness are also included in the above expressions.

This completes the formulae required to express the direction cosines $m$, $n$ in terms of the six orbital parameters and time $t$.

**The Differential Correction Procedure**

Let $l_i$ $(= 1,2,\ldots,N)$ be the computed set of direction cosines corresponding to times $t_i$ ($l_i$ may be either an '$m$' or an '$n$') and let $l_i'$ be the corresponding observed values, the residuals being

$$r_i = l_i - l_i'.$$

Now consider increments $\delta\alpha$, $\delta h_0$, $\delta\lambda$, $\delta\tau$ in the four quantities to be determined, and let $l_i''$ be the corresponding computed values of $l_i$ so that, to the first order,

$$l_i'' = l_i + \left(\frac{\partial l}{\partial \alpha}\right)_i \delta\alpha + \left(\frac{\partial l}{\partial h_0}\right)_i \delta h + \left(\frac{\partial l}{\partial \lambda}\right)_i \delta\lambda + \left(\frac{\partial l}{\partial \tau}\right)_i \delta\tau,$$

and if $R_i = l_i'' - l_i'$ are the new residuals,

then $$R_i = r_i + \left(\frac{\partial l}{\partial \alpha}\right)_i \delta\alpha + \left(\frac{\partial l}{\partial h_0}\right)_i \delta h + \left(\frac{\partial l}{\partial \lambda}\right)_i \delta\lambda + \left(\frac{\partial l}{\partial \tau}\right)_i \delta\tau,$$

$$(i = 1, 2, \ldots, N).$$

This is a set of $N$ linear equations in the four unknown increments, which may be solved by the standard procedure in such a way as to minimise $\Sigma R_i^2$.

Thus if

$$A = \begin{bmatrix} \left(\frac{\partial l}{\partial \alpha}\right)_1, & \left(\frac{\partial l}{\partial h_0}\right)_1, & \left(\frac{\partial l}{\partial \lambda}\right)_1, & \left(\frac{\partial l}{\partial \tau}\right)_1 \\ \left(\frac{\partial l}{\partial \alpha}\right)_2, & \cdots\cdots\cdots\cdots\cdots\cdots & & \\ \cdots\cdots\cdots\cdots\cdots\cdots & & & \\ \left(\frac{\partial l}{\partial \alpha}\right)_N, & \cdots\cdots\cdots\cdots\cdots\cdots & & \end{bmatrix}$$

$$v = \begin{bmatrix} \delta\alpha \\ \delta h_0 \\ \delta\lambda \\ \delta\tau \end{bmatrix} \quad \text{and} \quad \rho = \begin{bmatrix} r_1 \\ r_2 \\ \vdots \\ r_N \end{bmatrix}$$

the solution is

$$v = -C^{-1}A^*\rho$$

where the asterisk stands for transposition, and $C = A^*A$.

When the increments have been determined, the whole process is repeated with the new values $\alpha + \delta\alpha$, etc., and this is continued until there is no further improvement.

**Results of Observations of Sputnik 2**

The method outlined in the previous section has been used to analyse sequences of observations from the radio interferometer at Lasham, from kinetheodolites at Aberporth, Bramshot, Larkhill, Orfordness and West Freugh, and from theodolites at Jokioinen (Finland) and Woomera (South Australia). The radio interferometer observations[18] made during the first three weeks of life of Sputnik 1 and the first week of Sputnik 2 were useful for establishing the main features of the orbits but were not of the same order of accuracy as the later kinetheodolite and theodolite observations. The first accurate kinetheodolite observations were made of Sputnik 2 at Orfordness on November 9th, 1957, giving a height $h_0$ of $122{\cdot}4 \pm 0{\cdot}5$ nautical miles. This observation was very close to the perigee of the satellite and provided what proved to be the only direct measurement of $r_p$, the perigee radius vector, of $3556{\cdot}9 \pm 0{\cdot}5$ nautical miles. Subsequent estimates of $r_p$ have been obtained by combining indirect estimates from observations with the approximate formula (16) which is currently used in integrated form as

$$r_p = 3557{\cdot}3 - 7{\cdot}1 \ln\{165/(165 - t)\} \text{ nautical miles}$$

where $t$ is measured in days from 00 hours on 31 October, 1957.

The second parameter required for the digital computer analysis is the orbital period $T$; this has been obtained mainly from the large number of independent visual observations on which the prediction service for Sputnik 2 relied. A graph of $T$ against time for Sputnik 2 is shown in Fig. 17.

So far, eighteen sets of observations from kinetheodolite stations and eight sets from theodolite stations have been analysed to give values of the four

TABLE I.—*Elements of Sputnik 2*

| Station-Orbit No. | Time at Ascending Node, $T_\Omega$ | Nodal Period, $T$ (min.) | Semi-major Axis, $a$ (n. miles) | Eccentricity, $e$ | Right Ascension, $\Omega$ | Angle-Apex to perigee $\beta$ |
|---|---|---|---|---|---|---|
| O 101 | 1957 Nov. 9·21383 | 103·49 | 3940·2 | 0·0973 | 99°·87 | −32°·0 |
| O 409 | Dec. 1·22987 | 102·392 | 3912·36 | 0·0910 | 40°·84 | −41°·1 |
| O 423 | 2·22510 | 102·342 | 3911·09 | 0·0907 | 38°.15 | −41°·6 |
| O 437 | 3·21985 | 102·292 | 3909·81 | 0·0904 | 35°.48 | −42°.1 |
| A 438 | 3·29089 | 102·289 | 3909·74 | 0·0904 | 35°·28 | −42°·0 |
| J 479 | 6·20122 | 102·13 | 3905·7 | 0·0896 | 27°.50 | −43°·1 |
| B 827 | 30·73018 | 100·79 | 3871·4 | 0·0818 | 319°.90 | −52°·9 |
| A 841 | 31·70974 | 100·73 | 3869·9 | 0·0815 | 317°.21 | −53°·3 |
| A 1158 | 1958 Jan. 22·71781 | 99·211 | 3830·91 | 0·0728 | 254°.50 | −63°·1 |
| O 1158 | 22·71781 | 99·211 | 3830·91 | 0·0728 | 254°.52 | −63°·2 |
| B 1158 | 22·71781 | 99·211 | 3830·91 | 0·0728 | 254°.52 | −63°·3 |
| O 1159 | 22·78670 | 99·207 | 3830·80 | 0·0728 | 254°·32 | −63°·2 |
| B 1159 | 22·78670 | 99·207 | 3830·80 | 0·0728 | 254°.31 | −63°·3 |
| O 1187 | 24·71445 | 99·077 | 3827·46 | 0·0720 | 248°.74 | −64°·0 |
| F 1187 | 24·71445 | 99·077 | 3827·46 | 0·0720 | 248°.74 | −64°·0 |
| B 1188 | 24·78325 | 99·072 | 3827·33 | 0·0720 | 248°.53 | −64°·0 |
| W 1198 | 25·47106 | 99·03 | 3826·2 | 0·0717 | 246°.57 | −64°·5 |
| O 1443 | Feb. 11·22494 | 97·866 | 3796·20 | 0·0651 | 197°.27 | −71°·6 |
| O 1473 | 13·26197 | 97·70 | 3791·9 | 0·0641 | 191°.18 | −72°·6 |
| J 1904 | Mar. 14·15112 | 95·15 | 3725·6 | 0·0483 | 102°.38 | −85°·4 |
| J 1948 | 17·05296 | 94·799 | 3716·47 | 0·0461 | 93°.08 | −86°·5 |
| J 1949 | 17·11881 | 94·794 | 3716·34 | 0·0461 | 92°.94 | −86°·5 |
| L 2005 | 20·79630 | 94·335 | 3704·3 | 0·0434 | 81°.03 | −88°·8 |
| J 2035 | 22·75912 | 94·08 | 3697·5 | 0·0418 | 74°.61 | −89°·7 |
| J 2066 | 24·78189 | 93·82 | 3690·8 | 0·0402 | 68°.00 | −91°·0 |
| | ±·00001 | ±0·001 to 0·01 | ±0·06 to 0·3 | ±0·0006 | ±0°·05 | ±0°·2 |

Key: A = Aberporth.
B = Bramshot.
F = West Freugh.
J = Jokioinen (Finland).
L = Larkhill.
O = Orfordness.
W = Woomera (South Australia).

The Orbit Number is on the Nautical Almanac Office Scale, which is 16 greater than the actual number.

working parameters $\alpha$, $h_0$, $\lambda$, $\tau$. The first of these, the orbital inclination $\alpha$, has remained constant to within the accuracy of the observations, the mean value being $65{\cdot}°29 \pm 0{\cdot}03$. The other three parameters, being dependent upon the position of the observing stations, are not fundamental and will not be listed here. From the working parameters the values of the fundamental orbital elements have been determined and these are listed in Table 1, apart from the orbital inclination. The listed elements are

$T\Omega$, the time of the ascending node crossing,

$T$, the orbital (nodal) period, in minutes,

$a$, the semi-major axis, in nautical miles (1 nautical mile = 6,080 feet),

$e$, the eccentricity,

$\Omega$, the Right Ascension of the ascending node, relative to the vernal equinox of 1958·0

and $\beta$, the angle from apex to perigee.

$T\Omega$ has been preferred to the more usual "time of perigee passage" because of the greater accuracy with which it can be determined, and $\beta$ is preferred to the more usual "argument of perigee" to link up with the theoretical treatment of reference 3 ($\beta$ = argument of perigee minus 90°).

The accuracy with which the elements have been determined varies somewhat from observation to observation. Average values for the standard deviations are given at the foot of the table.

**Comparison of Theory with Observation**

The main predictions of the theories on the perturbing effects of air drag and of the oblateness of the Earth have been well borne out by the observations on the two Russian satellites. As predicted, the inclination of the orbital plane to the equator remains constant, and this is the only element which does so, the others varying with time.

**Effects of Earth's Oblateness**

The major effect of the oblateness of the Earth is the rotation of the orbital plane about the Earth's axis. The theoretical formula for the rate of rotation $\dot{\Omega}$ has been given (Equation 2). In order to compare this with the observed values of $\Omega$, the Right Ascension of the satellite, a sequence of observed values of $a$ and $\bar{r}$ together with the measured value of $\alpha$ have been inserted in Equation (2) and the resulting curve of $\dot{\Omega}$ versus time has been integrated numerically. The result, after the addition of a suitable integration constant, is shown in Fig. 13, together with the observed values of $\Omega$. The correspondence, at first sight, seems to be very good. Upon closer inspection, however, it appears that the observed rate $\dot{\Omega}$ is about 1 per cent. less than that given by the theoretical equation. If, as appears likely, this proves to be significant, we shall have to consider the possible causes of the discrepancy.

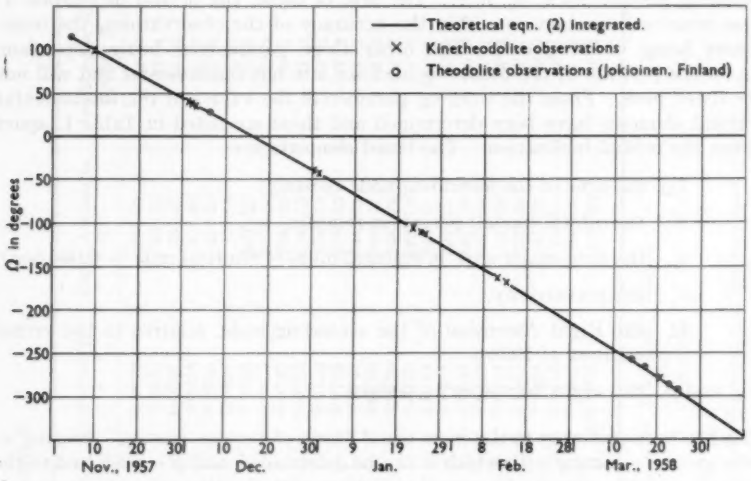


FIG. 13. Right ascension of the ascending node of Sputnik 2.

The second effect to be considered is the rotation of the major axis of the orbit. The theoretical formula for the rate of rotation $\dot{\beta}$ has been given (Equation 4). This has been integrated in the same way as $\dot{\Omega}$ above and the result is plotted in Fig. 14, together with the observed values of $\beta$. It will be seen that again the observed rate is slightly less than that given by the theoretical formula. In this case, however, the difference is not significant, as the factor $(5\cos^2\alpha - 1)$ in the theoretical formula is not known to better than one part in sixty, because of the observational error in $\alpha$.

The third effect of Earth's oblateness, namely the small periodic oscillations in the radial distance of the satellite, is too small to be detected by the observations which have been made so far.

**Effects of the Atmosphere**

The most searching test of the theories on the effects of air drag is provided by the period-versus-time curve of the satellite, which is known accurately from observation. The variation of period with time for the rocket of Sputnik 1 is shown in Fig. 11, together with the values given by the first-order theory, equation (19). The theoretical curve is fitted at the two ends of the observational curve. The value of $m/S$ for the rocket of Sputnik 1 is not known, but from a comparison with the period-time curve of Sputnik 1 itself (the 23-in. sphere of mass 184 lb.) it is surmised that the mean value of $m/S$ for the rocket was about 35 lb./ft.$^2$ The agreement between theory and observation in Fig. 15 is fairly good, but by no means perfect. It is quite possible, however, that the mean value of $m/S$ varied because of irregularities in the rotation of the

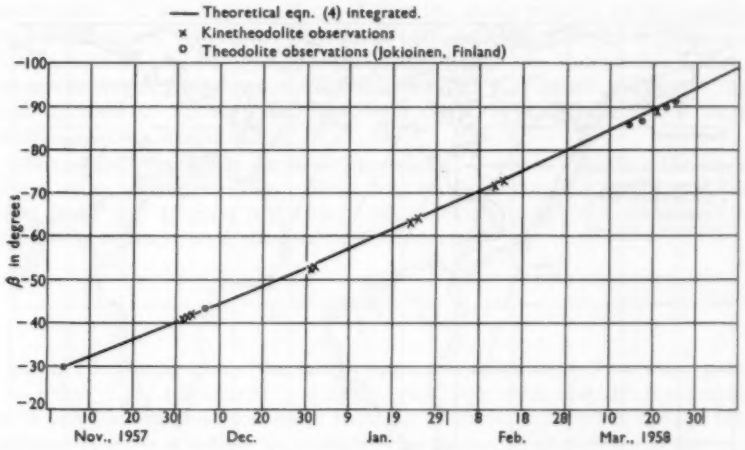


FIG. 14. Angle from apex to perigee of Sputnik 2.

rocket, and the theory cannot be expected to apply in these conditions. The last observed value of the period was 87·85 minutes at 22.40 hours U.T. on 30 November, and the appropriate rough formula for the remaining lifetime, similar to that already derived, is 0·06 $m/S$ revolutions, or about 2 revolutions if $m/S$ is taken as 35 lb./ft.$^2$ If this rough formula were correct the rocket would have entered upon its last revolution by the time it was sighted from California at 00.12 hours U.T. on 1 December, one revolution after the period fell to 87·85 minutes. Fig. 16 gives the path of the rocket on its last

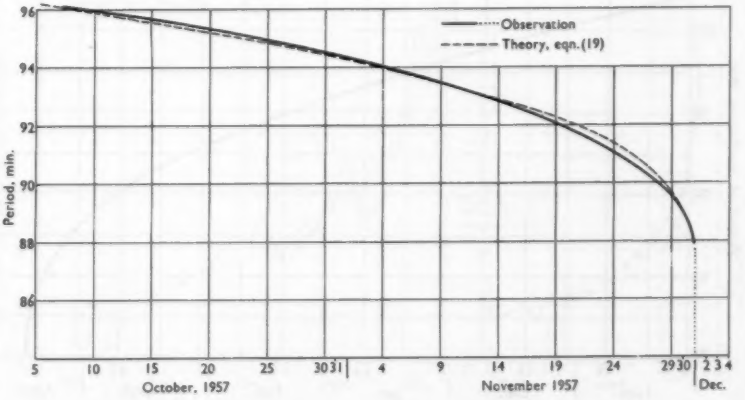


FIG. 15. Variation of period with time for the rocket of Sputnik 1.

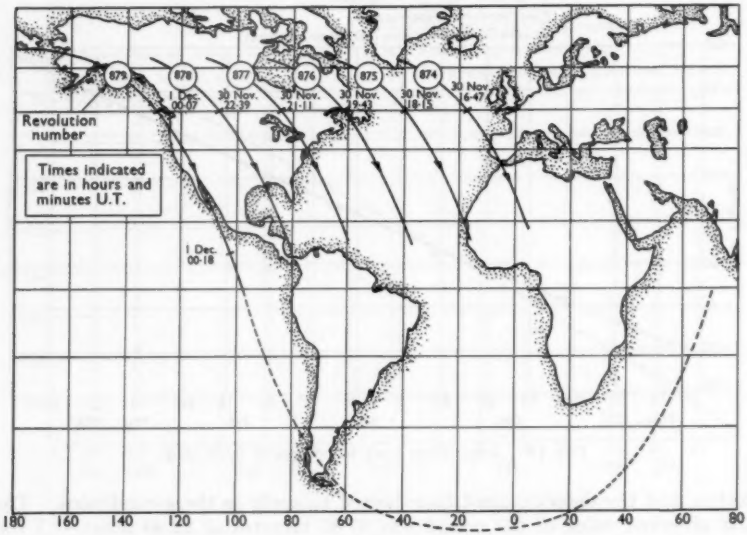


FIG. 16. The last hours of Sputnik 1 rocket, 30 November–1 December, 1957.
(See also *Note added in proof*, on p. 469.)

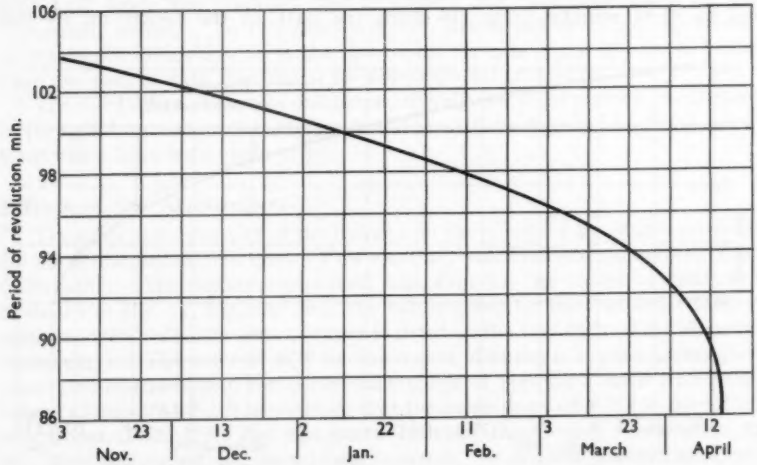


FIG. 17. Period of revolution of Sputnik 2 between November, 1957 and April, 1958.

revolutions. It should be emphasized that the above remarks on the descent of the rocket are somewhat speculative: a more careful study is obviously needed. (*Note added in proof:* papers presented at the Moscow I.G.Y. Conference in August 1958 suggest that the value of $m/S$ increased because the rocket ceased to tumble, and that as a result it completed a few more revolutions than shown in Fig. 16.)

The period-versus-time curve for Sputnik 2 is shown in Fig. 17. The slope of this curve, which is a measure of the drag acting on the satellite, fluctuated a great deal. Fig. 18 gives preliminary values for the rate of change of period, and the theoretical curve, obtained by differentiating (19),

$$-\frac{dT}{dt} = \frac{3e_0T_0}{4t_L\sqrt{1-t/t_L}} \qquad .. \quad .. \quad .. \quad (29)$$

is plotted for comparison (the initial point was taken as 4 November, with $e_0 = 0{\cdot}099$, $T_0 = 103{\cdot}76$ and $t_L = 161$ days.) It is seen that the theoretical curve provides quite a good mean value for the rate of decrease, though the fluctuations make it useless for prediction purposes. It should be emphasized that some of the observational points in Fig. 18 may be in error by as much as 0·3 sec./day. Some of the smaller fluctuations in the curve which has been drawn through the points may therefore be spurious. The larger fluctuations cannot be explained away like this however: they may be due to changes in the mode of rotation of the satellite, or to changes in density in the atmosphere, or to electrical effects, or to some other cause which has not yet been considered.

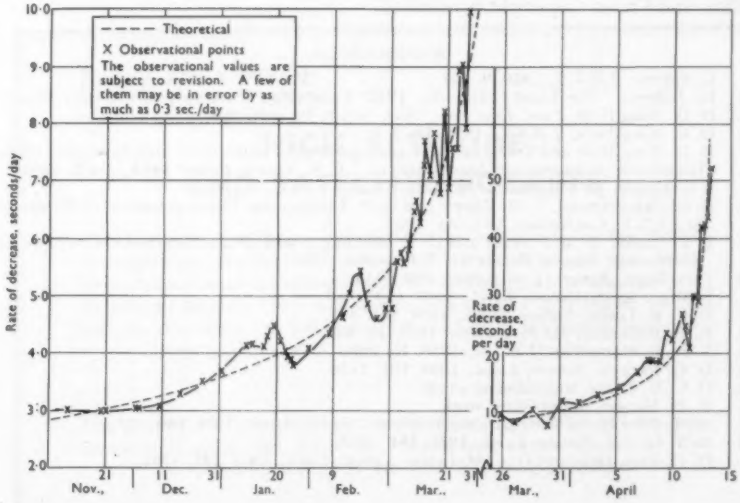


FIG. 18. Rate of change of period for Sputnik 2. Preliminary results.

## Conclusions

The theoretical predictions of the effect of the Earth's oblateness have been confirmed with good accuracy. The rate of rotation of the orbital plane, $d\Omega/dt$, can be determined accurately from observation, and by comparison with the theoretical value it may be possible, with a suitable satellite, to obtain better values for the fundamental constants of the Earth. Sputnik 2 has not been ideal for this purpose because it is possible that the aerodynamic forces acting on it were large enough to affect the value of $d\Omega/dt$ slightly.

The effects of the atmosphere on the motion of a satellite have not so far been in very good agreement with theory. In the case of Sputnik 2, the discrepancies can probably be ascribed to day-to-day variations in atmospheric density and changes in the mode of rotation of the satellite. The theory does, however, provide a most useful approximation, and it is expected that the lifetimes of future satellites will be predictable to within $\pm$ 10 per cent. very early in their careers.

## Acknowledgements

The practical results given in this paper have been obtained mainly from analysis of observations received from Dr. Järnefelt of Jokioinen Meteorological Observatory, Finland, from the kinetheodolite stations of the Royal Aircraft Establishment, and from the many observers on whose work the prediction service for Sputnik 2 relied. We wish to thank all those concerned for their efforts.

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## REFERENCES

1. L. Spitzer, *J.B.I.S.*, 1950, **9**, 131.
2. H. Jeffreys, "The Earth," 3rd edn., **1952**: Cambridge (Cambridge University Press).
3. D. G. King-Hele, *Proc. Roy. Soc.*, 1958, [A], to be published.
4. D. G. King-Hele, *J.B.I.S.*, 1956, **15**, 314.
5. D. G. King-Hele and D. M. C. Gilmore, unpublished Ministry of Supply report, 1956.
6. "Handbook of Supersonic Aerodynamics," *U.S. Navord Report* **1488**, April, 1950.
7. I. G. Henry, *Jet Propulsion*, 1957, **27**, 21.
8. D. C. Okhotsimskii, T. M. Eneev, and G. P. Taratynova, Paper presented at Washington I.G.Y. Conference, October, 1957.
9. T. E. Sterne, B. M. Folkart and G. F. Schilling, *Smithsonian Institution Astrophysical Observatory, Special Report No.* 7, December, 1957.
10. J. A. Fejer, *Nature, Lond.*, 1957, **180**, 1413.
11. J. M. C. Scott, *Nature, Lond.*, 1957, **180**, 1467.
12. D. C. M. Leslie, *Nature, Lond.*, 1958, **181**, 403.
13. R. E. Roberson, *Jet Propulsion*, 1958, **28**, 90.
14. T. R. F. Nonweiler, *J.B.I.S.*, 1958, **16**, 368.
15. D. G. Parkyn, *Nature, Lond.*, 1958, **181**, 1156.
16. D. C. M. Leslie, unpublished work.
17. R. H. Merson, unpublished work.
18. Staff of the Royal Aircraft Establishment, *Nature, Lond.*, 1957, **180**, 937.
19. G. V. Groves, *Nature, Lond.*, 1958, **181**, 1055.
20. D. G. King-Hele and D. C. M. Leslie, *Nature, Lond.*, 1958, **181**, 1761.

**Addendum**

Now that results for the whole lifetime of Sputnik 2 are available, it is found that the mean inclination of the orbit to the equator, $\alpha$, is not constant, but is given by

$$\alpha = 65°{\cdot}370 - 0°{\cdot}00100\, t \pm 0°{\cdot}02$$

where $t$ is the time in days after 00 hours on 3 November, 1957 (the values in Table I take account of this revised value of $\alpha$). This marked decrease in $\alpha$, at the rate of 0·001 deg./day, has not yet been satisfactorily explained. One possible approach is to remove the restrictive assumption that the Earth is symmetrical about the equatorial plane, and to add to $U$ an extra term

$$gR\, J_3 \frac{R^4}{r^4} \tfrac{1}{2}(5 \cos^3 \theta - 3 \cos \theta)$$

on the right-hand side of equation (1), where $J_3$ is a coefficient whose value is unknown, though it must be very small to have escaped detection in geodesy. Using this new form for $U$ a theoretical value for $\dot{\alpha}$ can be found, and it contains terms in $J_3 e$, and $De^2$ and $J^2 e$. The value of $\dot{\alpha}$ given by this formula does not appear to be large enough to account for the observed change, however, and other possible causes, such as the rotation of the atmosphere, are being investigated.

With the new values of $\alpha$ it is found that the theoretical value of $\dot{\Omega}$, as given by (2), exceeds the observational value by a factor $1{\cdot}0068 \pm 0{\cdot}0003$. Since this factor remained virtually constant during the lifetime of Sputnik 2 it seems highly improbable that the discrepancy is due to atmospheric effects, which should increase steadily as time goes on; the effect of asymmetry about the equator can also be discounted, since it leads to a term in $\dot{\Omega}$ with coefficient $J_3 e$, which should decrease markedly during the lifetime of the satellite. Thus it seems probable that one or both of the constants $J$ and $D$ is in need of revision. The discrepancy between the observed and theoretical values of $\dot{\Omega}$ could be explained either by a change in $J$ from 0·001637 to 0·001626 or by a change in $D$ from $10{\cdot}6 \times 10^{-6}$ to $45 \times 10^{-6}$. The change in $J$ would correspond to a change in the Earth's flattening from 1/297·1 to 1/298·1, but it appears likely that it is $D$ which is more in need of revision. If accurate observations were available on another satellite with different orbital inclination it would be possible to decide how much change is needed in each of the two coefficients.

***Ready Next Month***

**HIGH ALTITUDE AND SATELLITE ROCKETS**

The proceedings of the Joint Symposium sponsored by the British Interplanetary Society, the College of Aeronautics, and the Royal Aeronautical Society, which was held at the College of Aeronautics from 18 July to 20 July, 1957, will shortly be published as a bound volume with the above title. It will include the full text of the papers, communications and discussion, together with a list of the delegates.

The price of the volume is £1 12s. 6d. (plus 1s. postage) ($5.00), but members of either the B.I.S. or R.Ae.S. may obtain a copy at the privileged price of £1 2s. 6d. (plus 1s. postage) ($3.50).

# SPACE LAW AND METALAW: JURISDICTION DEFINED*

By ANDREW G. HALEY,† B.A., Ll.B., FELLOW

SUMMARY

Reviews opinions of some authorities on the subject of space law and discusses demarcation of regions of air and space jurisdiction.

In his excellent review of the papers delivered at the VIIth Annual Congress of the International Astronautical Federation in Rome, Italy, 17–22 September, 1956, Slater[1] remarked with respect to my paper,[2] *Space Law and Metalaw: A Synoptic View*, that I was deficient with regard to definitions. Having wholesome respect for Slater's power of analysis and criticism, I re-read my paper with the thought that I might perform a useful task in clarifying the meaning of the terms I had used therein.

My reassessment of the Rome paper satisfied me that I had adequately defined anthropocentric law as being simply the law of human beings, and in this connection the term *law* is frequently employed as referring to a science of principles; and, specifically, a science or system of principles or rules of human conduct; "a system of rules and principles, in which the rights of parties are protected and enforced; a system of rules conformable to the standards of justice and on an enlarged view of the relations of persons and things as they practically exist; a mass of principles classified, reduced to order, and put in the shape of rules, agreed on by ascertaining the common consent of mankind; rules of civil conduct for the common good; rules promulgated by government as a means to an ordered society; the enforcement of justice among men." It is also said that the very definition of law is *sancto sancti jubens honesta et prohibens contraria*.

I also believe that terrestrial law, international law, natural law, and similar concepts of law have been discussed adequately.[2,3]

A meticulous review of the writings of experts in the field, as well as my own papers on the subject, left me with the belief that it is most desirable to state as finally as possible a scientific definition of the precise area where the jurisdiction of terrestrial law ends and the jurisdiction of space law begins. To arrive at such a determination, it is desirable, and indeed necessary, to review the opinions of the authorities on the subject, and then come to some basic conclusions.

However, because of the failure of publicists to furnish the Library of Congress with their writings—and the consequent lack of the indexing thereof in the United States—I undoubtedly have not consulted the writings of all the authorities who have dealt with space law.

Professor John Cobb Cooper, one of the most competent world authorities and undoubtedly the Dean of American air law experts has written[4]:

* Paper presented at American Rocket Society Spring Meeting, Washington, D.C., 3–6 April, 1957.

† President, International Astronautical Federation; General Counsel of the American Rocket Society.

"Certain jurists have insisted that the territory of a State is limited by the ability of that State to make its law effective. This is a harsh rule when applied to sovereignty in space. The richest and most powerful States now have means through high altitude rockets to control more or less effectively the 'airspace' over their surface territories. But the weaker States have no such power. Can we be said to live in such a world where the physical power at any one time of any particular State determines its *international right* to consider the region above its surface territories as part of its national territory? I may say here that my own belief is and has always been that if the rule of effectiveness is to be applied to determine the limit of State territory in space, then the rule should be that every State, no matter how small or how weak, as a State of equal sovereignty with every other State, has and should be admitted to have territorial rights upwards above its surface territories as high as the rights of every other State, no matter how powerful.

Perhaps the rule should be, in the absence of international agreement, that the territory of every State extends upward as far into space as it is physically and scientifically possible for any one State to control the regions directly above it. In considering the possibility of adopting such a rule as this as part of international law, its limitation must be understood. The enormous distances must not be forgotten. . . ."

These observations of Professor Cooper have been misinterpreted on numerous occasions during the past several years. He continued, in the same article:

". . . I am concerned that we must abandon the theory that the State has the right to claim territory out into space as far as the Earth's attraction extends, and that we must admit some such reasonable rules as I have suggested above—namely, that at any particular time the territory of each State extends upward into space as far as the scientific progress of any State in the international community permits such State to control space above it.

Frankly, this is not put forward as a final solution. It is realized that it leaves open such vital questions as to what extent of control is contemplated, and by what means an international determination will be made of the ability of the most powerful State to extend its control into outer space. In its favour I can only say that it is worthy of consideration; that it provides the basis for a fairly livable world in which the weak State is not at the mercy of the strong."

In 1956, Professor Cooper[5] summarized his current thinking by proposing a three-zone concept of sovereignty created through an international convention on the subject. He suggested that we:

"Reaffirm Article I of the Chicago Convention, giving the subjacent State full sovereignty in the areas of atmospheric space above it, up to the height where 'aircraft' as now defined, may be operated, such areas to be designated 'territorial' space.

Extend the sovereignty of the subjacent State upward to 300 miles above the Earth's surface, designating this second area as 'contiguous space,' and provide for a right of transit through this zone for all non-military flight instrumentalities when ascending or descending.

Accept the principle that all space above "contigous space' is free for the passage of all instrumentalities."

Dr. Alex Meyer,[6] of the University of Cologne, commented on these views as follows:

"I agree fully with Professor Cooper that the only way to solve the question concerning the legal status of the outer space is an international agreement and, in my opinion, the solution can only be to consider the outer space as a free area like the open sea. In my opinion it seems quite impossible to extend the States' sovereignty into the outer space. Besides the fact that the exercise of such sovereignty in the outer space cannot become effective, it seems impossible to fix an area in the outer space which corresponds to the territory of a State on the Earth. The enormous distances between the surface of the Earth and the outer space makes it impossible to state whether an event occurring in the outer space has occurred just above a certain State of the Earth. Even by establishing

fictitious borderlines above the territorial boundaries of a State, it seems impossible to fix an area in the outer space which corresponds exactly to these territorial boundaries.

On the other hand, I have some doubt whether it would be necessary or even useful to establish a 'contiguous area,' evidently similar to the territorial waters of the Earth. The situation of the air and the outer space is quite different from the situation on the Earth. Between airspace and outer space no determined shore exists. The air has the particular quality of gradually becoming thinner and thinner. As soon as there is traffic into the outer space, it will of course be necessary to fix the limits between the airspace and the outer space in a certain altitude by an international agreement. At which height these boundaries should be fixed, will be a question to be decided by the experts.

As concerns the additional questions of Professor Cooper whether ICAO should be authorized to amend its Annexes, so as to expand its definition of 'aircraft' to include instrumentalities which, like rockets and satellites, do not require support from the air, and thereby extend its regulatory jurisdiction to such new flight instrumentalities, I do not think it possible to include rockets and satellites which do not require support from the air within the term 'aircraft.' I think a different term must be used for these instrumentalities. Mr. Cooper has already used the name 'spacecraft,' the name 'spaceship' has also been used. On the other hand, it would be possible to extend the regulations of the Convention of Chicago with the necessary amendments to the new flight instrumentalities."

A Nationalist Chinese Scholar, Ming-Min Peng,[7] takes a contrasting position. He maintains that at least until interplanetary travel becomes a reality, the sovereignty of nations over the space above them should be considered to extend to the limits of all flight. He points out that the operative scope of the Chicago Convention of 1944, which embraced the national sovereignty principle, extends to the outermost part of the atmosphere and he justifies its use despite all practical difficulties on the ground of the immense danger to subjacent States which otherwise must exist.

Ming-Min Peng argues that nations have always considered themselves supreme in the whole area above their territory and that the sovereignty statements in the Conventions of this century were never considered by the contracting parties to be limitative in nature, but went to the limits of space thought to be usable by man.

C. Wilfred Jenks,[8] of the International Labour Office, takes the position that the national sovereignty concept cannot be applied beyond the Earth's atmosphere because the realities of interstellar space make such a concept "a meaningless and dangerous abstraction." He argues that space beyond the Earth's atmosphere is analogous to the high seas and is and must remain incapable of appropriation by the projection into it of any particular sovereignty based on a fraction of the Earth's surface. He cites the satellite launching plan as an example of the acceptance of his thesis on State practice. Jenks states:

". . . that the present law relating to sovereignty over air space . . . may be regarded by future generations much as we regard the claims to maritime sovereignty which were more or less successfully asserted for several hundreds of years before Grotius and Bynkershoek established the principle of the freedom of the seas. Space beyond the atmosphere of the Earth presents a much closer analogy to the high seas than to the air space above the territory of a State. One could, theoretically, conceive of the atmosphere, the ionosphere, the zone used by Earth satellites and interplanetary and interstellar space beyond as a series of zones subject to differing legal régimes. There would, however, be serious difficulty in defining the boundaries of the successive zones. Even if this difficulty were overcome and such an approach to the problem were to be adopted the projection of the territorial sovereignty of a State beyond the atmosphere above its territory would be so wholly out of relation to the scale of the universe as to be ridiculous; it would be rather like the Island of St. Helena claiming jurisdiction over the Atlantic.

". . . any projection of territorial sovereignty into space beyond the atmosphere would be inconsistent with the basic astronomical facts. The revolution of the Earth on its own axis, its rotation around the Sun, and the planets through the galaxy all require that the relationship of particular sovereignties on the surface of the Earth to space beyond the atmosphere is never constant for the smallest conceivable fraction of time. Such a projection into space of sovereignties based on particular areas of the Earth's surface would give us a series of adjacent irregularly shaped cones with a constantly changing content . . . missiles, space stations and space ships moving in space would be constantly changing their position in relation to the subjacent territorial sovereignties at such high speeds that whatever relationship of control might subsist between Earth stations and such objects in space would have no territorial aspect analogous to the control exerted by a State in its air space or territorial waters. Only activities within the atmosphere of the Earth would appear to be susceptible of a degree of control similar in general nature to that which can be exercised in territorial waters or over a wider maritime frontier belt. By reason of the basic astronomical facts, space beyond the atmosphere of the Earth is and must always be a *res extra commercium* incapable of appropriation by the projection into such space of any particular sovereignty based on a fraction of the Earth's surface. . . ."

Summing up his position, Jenks says:

"1. Space beyond the atmosphere is a *res extra commercium* incapable by its nature of appropriation on behalf of any particular sovereignty.

2. It is most desirable that jurisdiction over activities in space beyond the atmosphere should be recognized to be vested in the United Nations and that legislative authority over activities beyond the atmosphere of the Earth should be exercised by the General Assembly acting through or on the advice of an appropriately constituted body. If the political difficulties can be overcome, such an international solution of the problem of jurisdiction in space presents no insuperable legal difficulties.

3. Failing such an international solution of the problem of jurisdiction in space beyond the atmosphere, it will be necessary to determine such jurisdiction on the basis of appropriate criteria inspired by analogies drawn from maritime and aviation law and to develop common international rules and standards governing the wide range of problems which would arise.

4. Rules governing the extent to which, and manner in which, national authorities may protect themselves against interference from space beyond the atmosphere with matters within their territorial jurisdiction or interfere, by electronic or other means, with activities in space for the purpose of making such protection effective, or for other reasons, will be necessary."

Oscar Schachter, Director of the General Legal Division of the United Nations, has made several contributions in the field of space law, including a paper in this *Journal*.[9] In another article[10] he stated:

". . . It is obviously of some importance to the future of space travel to know precisely what is meant by the term 'airspace' as used in international law. Does the term 'air' extend only to the upper atmospheric regions? Should it be defined in terms of the composition and/or density of the gases? So far there has been no authoritative answer to this question. The reasonable answer, it would seem, is to consider that the term is used in aviation treaties and therefore it is presumably intended to refer to the part of the atmosphere which contains enough air to allow aircraft (including balloons) to fly. Up to now balloons have gone as high as 21 miles, but it is estimated that air sufficient for flight extends about twice as high above the Earth. Beyond that there is no airspace so far as aircraft are concerned.

Whatever may be the precise boundary of the airspace, it is clear that when we go beyond it we are legally in a no-man's world. Before rocket ships were conceived of, some jurists maintained that there could be no upper limits to the territory of a state. A legal argument put forward for this was that 'in the air, the higher one ascends, the more damage a fall of objects will cause on the Earth.' Consequently, since a country has the right to protect itself, it should have the right to control, as its territory, those areas above it which, if used by others, could involve damage to the country below. On this theory, the territory of a country would presumably extend upward as high as the Earth exercises gravity over an object shot off into space—that is, as far as the farthest point from which a rocket would fall back on the Earth.

Although this approach might have seemed plausible to international lawyers years ago, it can hardly be justified when we consider its possible application. In the first place, the effect of the gravitational pull of the Earth on an object varies with the shape of the object and the speed with which it moves. Obviously, therefore, it would be impossible to fix boundaries on the assumption that objects within these boundaries would fall back on the Earth. Even if it were decided to establish an arbitrary limit (which would be related to the pull of gravity exerted on a rocket ship moving at a given speed), there would be great practical difficulties. For example, a rocket ship moving at, say, 25,000 miles per hour would not remain long over the territory of the country from which it started. It would pass through several countries—providing we extended their territories upward considerably beyond the 'air-space,' but it would be extremely difficult —indeed, practically impossible—for those in the rocket ship to know when it left one country and entered another.

Similarly, the space station, held in its orbit by the force of gravity and moving 1,075 miles above the rotating Earth at 15,840 miles per hour, would be passing over national territories, but it would be quite impossible to ascertain in practice when it crossed the theoretical boundary lines.

Thus, the whole idea of determining the height of national territory in terms of gravity is not only unsound scientifically, but quite useless from the standpoint of legal rules.

It has been proposed that the upper territory be limited in terms of a nation's power to exercise effective control. Presumably, this means that if a State can 'control' (that is, stop) the flight of another State's rocket ship or guided missile at a certain distance, then territorial sovereignty should be limited to that distance. This position has been put forward by a distinguished authority, John C. Cooper, the Director of the Institute of International Law. He has proposed 'that at any particular time, the territory of each State extends upward into space as far as the then scientific progress of any State in the international community permits such State to control space above it.'

It is interesting to note the resemblance between this approach and the old 3-mile rule which has fixed the area of a country out into the ocean. This 3-mile rule was also based on the idea of effective control—in particular, on the range of shore-based artillery batteries. At the end of the eighteenth century, these batteries had a range of about 3 miles, and therefore it was considered that that portion of the sea was within the control of the State.

Although the principle of effective control has been important in international law, one wonders whether it should be applied to this new problem of space travel. It would seem to mean that whenever a country could prevent or interfere with the movement of a rocket ship or space station it would have the legal right to do so. Would this not, in effect, simply be a rule that 'might makes right'? And would it not place rocket ships and space stations at the mercy of those national States which were able to interfere with their free passage?

There certainly does not appear to be any compelling reason in law or principle to carry national sovereignty this far. Indeed, any attempt to extend national territory higher than the airspace is bound to involve difficulties. Why not, then, fix the limit at the upper boundary of the airspace and no higher?

Beyond the airspace, as already noted, we would apply a system similar to that followed on the high seas; outer space and the celestial bodies would be the common property of all mankind, over which no nation would be permitted to exercise domination. A legal order would be developed on the principle of free and equal use, with the object of furthering scientific research and investigation. It seems to me that a development of this kind would dramatically emphasize the common heritage of humanity and would serve, perhaps significantly, to strengthen the sense of international community which is so vital to the development of a peaceful and secure world order."

Dr. Welf Heinrich, Prince of Hanover,[11] discusses the problems of sovereignty and jurisdiction:

". . . one ought to examine whether the reasons arguing in favour of extending the sovereignty into the air space above the national territories might safely be applied to the area beyond the atmosphere stretching above these national territories.

This, however, would have to be answered in the negative. . . . all those facts which make the close affinity of the air space with the Earth appear to accord with the laws of nature, in no way apply to the vacuum beyond the atmosphere, for only the air-filled

regions are so automatically connected with life on the surface of the Earth that they may be considered part of it. This 'correlation determined by considerations of space and sovereignty,' however, does not exist between the area beyond the atmosphere and the lands and waters underneath it. Thus, the area beyond the atmosphere cannot be considered an 'integral part' of any national territory. . . . two conditions will have to be fulfilled for a nation to exercise its sovereignty over a certain area:

> There must be an area with frontiers which although invisible, will be capable of being determined. On the other hand there must be a possibility of exercising 'effective control.'

Both conditions, however, do not apply in the case of regions beyond the atmosphere.

Even when drawing imaginary frontiers above the boundaries of a country it will be quite impossible, within the limits of our present technical development, to ascertain whether some event has taken place above the territorial frontiers of a certain state.

Such national frontiers can no longer be determined with the kind of distances there are between the surface of the Earth and the regions beyond the atmosphere.

With the entire solar system perpetually in motion and the Earth, involved in this process of perpetual motion, travelling along a fixed course while itself rotating, an extension of vertical frontiers from the Earth into the area beyond the atmosphere would be out of the question.

Admittedly, in order to exercise the sovereignty an actual occupation within the meaning of the law of things need not have taken place . . . nor will the authority of the state be required to show itself continuously. Equally, there is no fixed rule according to which a nation should meet immediately and directly on the spot every objectionable action directed against it from the territory in question.

On the other hand there must be a possibility to exercise control.

The fact that we are already in a position to have rockets penetrate for a short time into the area beyond the atmosphere, cannot be held to constitute a 'possibility to exercise control' over regions beyond the atmosphere.

Thus, to extend the sovereignty of a ground State into the area beyond the atmosphere above its territory hardly seems to be a practical proposition, even if limits be determined for such regions."

* * * * *

"On all these grounds an extension of national sovereignty into the area beyond the atmosphere will be inadmissible, with the result that this area must be deemed free territory just like the air space above the high seas and regions outside the jurisdiction of any State."

It will be noted from the foregoing review that the general idea of space law sovereignty and jurisdiction has finally become fairly well thought out. After concluding the review, it seemed to me that the jurisdiction of space law might well be defined in scientific accuracy. A paper by Dr. Theodore von Karman[12] reproduced a diagram made by Masson and Gazley of the Rand Corporation which indicated the possible ranges for continuous flight in the velocity/altitude coordinate system (the diagram was designed to show the variation of velocity versus altitude for various values of dynamic pressure and equilibrium pressure). I have redrawn this diagram to indicate curves showing the high altitude sounding rocket régime, the Earth orbital satellite régime and the Kepler régime (Earth escape velocity), and some supernumerary information (Fig. 1).

To establish sound bases for demarcation of air and space jurisdiction it is necessary to consider that the condition for accomplishing aerial flight, that is to circle at constant altitude, is:

$$\text{weight} = \text{aerodynamic lift} + \text{"centrifugal force."}$$

The aerodynamic lift decreases with altitude because of the decreasing density of the air, and in order to maintain continued flight beyond zero air lift, "centrifugal force" must take over. Consider the flight of Captain Ivan C.

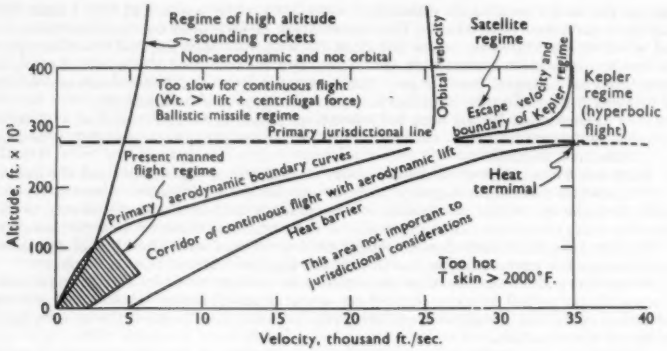


FIG. 1. Diagram showing régimes of atmospheric and extra-atmospheric flight and depicting the jurisdictional boundary lines (*Haley extrapolat*).

Kincheloe, in which he took the X2 rocket plane to 126,000 ft. altitude. His flight was strictly an aeronautical adventure and did not partake of space flight. At the altitude indicated, aerodynamic lift carries 98 per cent. of the weight and only 2 per cent. is "centrifugal force," or "Kepler force." It will be noted that in the corridor of continuous flight when an object reaches approximately 275,000 ft. and is travelling at 35,000 ft./sec., the "Kepler force" takes over and aerodynamic lift is gone. This is a critical jurisdictional boundary.

I have reproduced the Masson and Gazley right-side curve—the so-called temperature barrier, or heat barrier—simply to show the present state of the art, and thus arbitrarily to delimit the corridor of continuous flight. This line has nothing to do with the jurisdictional question as improved techniques in cooling and discovery of heat resisting materials will undoubtedly change this curve.

One scientific principle must be crystal-clear in the minds of the lawyer and the statesman, namely, the legal problems involved in space travel and exploration are unlike and are different in kind from those involved in maritime navigation and in air navigation, and only very limited analogies may be derived from the corpus of maritime and air law.

On a number of occasions, treaty makers and judicial bodies have had to face up to the solution of legal problems in connection with new developments in civilization. We will discuss this point very briefly and refer only to a few American authorities.

Justice Brandeis, in *Jaybird Mining Co.* v. *Weir*,[13] stated that:

> "It is a peculiar virtue of our system of law . . . that an expression in an opinion yields later to the impacts of facts unseen."

Justice Cardozo, in *Paradoxes of Legal Science*,[14] pointed out that:

> "The impact may come from a new fact. It may come from a changing estimate of policy or justice. . . . What was ruled or next to ruled was well enough often according to the wisdom of its day. The light of a new day has set it forth as folly. . . . *Stare decisis* perpetuates error, prevents courts from adopting the law of the changed needs

and desires to society, . . . it is an abdication of reasoning power, judgment and responsibility of the present generation of lawyers."

Solomon Goldman[15] quotes Justice Brandeis as saying:

"In differentiation, not in uniformity lies the path of progress."

Chief Judge Loughran, of the Court of Appeals, State of New York, has pointed out[16] that

". . . I cannot go along with those who insist upon a rigid and mechanical adherence to the decisions of the past, without regard to the impact of later day social, economical and political changes that have been wrought in the world about us. Indeed if we were to be limited to slavish adherence to precedents and were not free to apply the decisions and their underlying principles to changing conditions and situations which did not exist and were not contemplated when the decisions were made, our decisional law would in great measure be no more advanced today than it was generations ago. . . . The danger is ever present that deference to the teachings of the past may lead us to approach current issues with minds attuned only to the spirit and attributes of a bygone day and may deprive us of the quality of being responsive to the needs and interests of the here and now."

Again, Justice Brandeis, in *Burnet* v. *Coronado Oil and Gas Co.*,[17] wrote,

". . . Where correction through legislative action is practically impossible, this Court has often overruled its earlier decisions. The Court bows to the lessons of experience and the force of better reasoning, recognizing that the process of trial and error so fruitful in the physical sciences is appropriate also to the judicial form."

Justice Holmes summed up his viewpoints by stating, in *The Path of the Law*,[18] that

". . . it is revolting to have no better reason for a rule of law than that it was laid down in the time of Henry IV."

In a philosophical tenor, John Dewey[19] wrote,

"Here is where the great practical evil of the doctrine of immutable and necessary antecedent rules comes in. It sanctifies the old; adherence to it in practice constantly widens the gap between the current social conditions and the principles used by the courts. . . . The sanctification of ready-made antecedent universal principles as methods of thinking is the chief obstacle to the kind of thinking which is the indispensable prerequisite of steady, secure and intelligent social reforms in general, and social advance by means of law in particular. If this be so, infiltration into law of a more experimental and inflexible logic is a social as well as an intellectual need."

Justice Frankfurter, in *Braniff Airways* v. *Nebraska Bd.*,[20] stated that:

"One of the most treacherous tendencies in legal reasoning is the transfer of generalizations developed for one set of situations to seemingly analogous, yet essentially very different, situations."

The folklore and the philosophy of the law were authoritatively and finally handled by the Supreme Court of the United States in *Chicago & Southern Air Lines* v. *Waterman Steamship Corporation*,[21] in which the Court stated its determination that:

"The resemblance to water, rail and motor traffic must not blind us to the fact that legally, as well as literally, air commerce . . . has soared into a different realm than any that has gone before. . . ."

The problems of maritime law and air law are susceptible of many common solutions arising from two basic affinities, namely (*a*) each medium is essentially terrestrial and is limited to terrestrial considerations, and (*b*) in each medium navigation is in a fluid ocean—air or water. The ability to fly or to float depends upon a terrestrial substance—and navigation does not depend upon "centrifugal force" or upon what we have called the "Kepler force."

No physical boundary could be more stark or real than the boundary shown in Fig. 1 where the régime of aerodynamic lift ends and the régime of the "Kepler force" takes over.

This complete mechanical dichotomy bequeaths to any animal conditioned to Earth fundamentally new physiological and psychological problems, *i.e.*, the problems of existence in the terrestrial media are fundamentally different from the problems of existence in free space. Once we are no longer earthbound we have entered into a new existence which must be governed by new sets of rules and regulations.

The legal problems which will arise in connection with space travel will be vastly more complicated and in many respects entirely different from those which faced civilization when it abandoned God's wind for the steamship and when it took to flight in the air.

As to man *qua* man, many of the common relationships established in the vast body of anthropocentric law will have to continue in space. Among these are the simple laws of Moses known to the Western World as The Ten Commandments. But many of our concepts of terrestrial municipal law and positive international law must be abandoned.

This conclusion seems to be well supported by the authorities whose writings I have reviewed above. It is quite interesting to note that Professor Cooper's second area of jurisdiction, which he calls "contiguous space," quite naturally flows from the curve on Fig. 1 delimiting the boundary of the Earth-orbiting satellite régime. We thus find scientific basis for Professor Cooper's second zone and we also may find philosphical justification for his second zone as he states that we must "provide for a right of transit through this zone for all non-military flight instrumentalities when ascending or descending." Professor Cooper adds that "we must accept the principle that all space above 'contiguous space' is free for the passage of all instrumentalities."

I have studied with care both the papers of Professor Cooper and Dr. Meyer and, despite the scientific basis for Professor Cooper's second zone, at the present time I can think of no useful legal reason for the existence of such a zone as an area of legal regulation other than the obvious possibility of extending nationalistic territorial jurisdiction into this zone. The main purpose of this latter proposition would be to project into the second zone all the rules and regulations now part of municipal law and international law governing aeronautical navigation. As I am opposed to such an extension in principle, I must express my current caveat. I have lingering doubt as to the soundness of my position but I am sure that further thinking on the matter by all concerned will lead to clear solutions.

In his State of the Union Message to Congress on January 10, 1957, President Eisenhower said:

> "A sound and safeguarded agreement for open skies, unarmed aerial sentinels, and reduced armament would provide its valuable contribution towards a durable peace in the years ahead. And we have been persistent in our efforts to reach such an agreement. We are willing to enter any reliable agreement which would reverse the trend toward ever more devastating nuclear weapons; reciprocally provide against the possibility of surprise attack; mutually control the outer space missile and satellite development; and make feasible a lower level of armaments and armed forces and an earlier burden of military expenditures. Our continuing negotiations in this field are a major part of our quest for a confident peace in this atomic age."

One week later, Henry Cabot Lodge, Jnr., United States Representative to the General Assembly of the United Nations, outlined the proposed United States plan before the Political and Security Committee of the United Nations. He said, on January 14:

> "My statement today . . . will look more to the future than to the past. . . . Only recently, in his letter to Marshal Bulganin of December 31, 1956, President Eisenhower[22] affirmed his belief that 'deliberations within the framework of the United Nations seem most likely to produce a step forward in the highly complicated matter of disarmament.' President Eisenhower also declared the intention of the United States to submit new proposals in the United Nations."

Ambassador Lodge pointed out that the new proposals would centre upon five points. One point, in his words, would be: "To insure that research and development activities concerning the propulsion of objects through outer space be devoted exclusively to scientific and peaceful purposes." Elaborating on this point, Mr. Lodge stated[23]:

> "Scientists in many nations are now proceeding with efforts to propel objects through outer space and to travel in the distant areas beyond the Earth's atmospheric envelope. The scope of these experiments is variously indicated in the terms of 'Earth satellites,' 'intercontinental missiles,' 'long-range unmanned weapons,' and 'space platforms.' No one can now predict with certainty what will develop from man's excursion in this new field. But it is clear that, if this advance into the unknown is to be a blessing rather than a curse, the efforts of all nations in this field need to be brought within the purview of a reliable armaments-control system. The United States proposes that the first step toward the objective of assuring that future developments in outer space would be devoted exclusively to peaceful and scientific purposes would be to bring the testing of such objects under international inspection and participation. The United States Earth satellite presently planned for the International Geophysical Year is an example of an open project devoted exclusively to scientific purposes and developed with the knowledge and approbation of the scientists of the nations represented in the International Geophysical Year. In this matter, as in other matters, we are ready to participate in fair, balanced, reliable systems of control."

Great Britain immediately endorsed the United States plan. But Russia just as swiftly condemned it. Vassily V. Kuznetsov, U.S.S.R. foreign minister, argued that the United States had air bases sufficiently close to Russia so that long-range missiles would not be needed. Russia, on the other hand, has no such bases, Kuznetsov asserted, and must therefore depend on long-range missiles. Consequently, Russia will demand that the United States give up NATO bases before Russia will agree to the control of long-range missile experimentation.

In spite of this Russian opposition, the General Assembly of the United Nations, on January 25, 1957, adopted a resolution recommending that the Disarmament Commission give "prompt attention" to the proposals, and further recommending that a report of progress be issued not later than August 1, 1957.

While past experience has indicated that progress for such a proposal may be rather slow, there is satisfaction in knowing that this problem is, for the first time, being discussed by the United Nations. While initially, international control under such a proposal would extend only to international participation and inspection in testing of such objects, eventually the objects themselves would be subjected to international control and kept "peace loving."[24]

I deeply regret that the United States has handled this matter in the manner shown by the record. The IGY Earth-circling satellite programme should never have been the subject of discussion in connection with the Disarmament Commission.

This paper would not be complete without mention of the increasing awareness of the problems of extraterrestrial exploration by Members of Congress. In January of 1957, Representative Frank M. Karsten introduced a Bill in the U.S. House of Representatives to create a joint Congressional Committee on extraterrestrial exploration to make "continuing studies of activities and problems relating to the development of extraterrestrial exploration and travel." This Bill is similar to one introduced by Mr. Karsten in 1955. While the earlier Bill failed to receive the support that it merited, it is believed that the increasing awareness of the problems of space exploration over the past few years will assure Mr. Karsten's present Bill of a better reception.

## REFERENCES


(1) A. E. Slater, *J.B.I.S.*, 1957, **16**, 22.
(2) A. G. Haley, *Harv. Law Rec.*, 8 Nov., 1956, **23**, (6); *Proc. VII Int. Astronaut. Congr.*, **1956**, 435.
(3) A. G. Haley, *Jet Propulsion*, 1955, **25**, 627; *ibid.*, 1956, **26**, 951; *ibid.*, 1957, **27**, 60; *Tenn. Law Rev.*, 1956, **24**, 643; *Harv. Law Rec.*, 7 Feb., 1957, **24**, (2), Special Supplement, 1–4; *Z. Luftrecht*, 1957, **6**, 59.
(4) J. C. Cooper, *Int. Law Quart.*, 1951, **4**, 411.
(5) J. C. Cooper, *Proc. Amer. Soc. int. Law* (*50th Annual Meeting, Washington, D.C.*, 25–28 April, 1956, p. 85.
(6) A. Meyer, *ibid.*, p. 96 (discussion).
(7) Ming-Min Peng, *Rev. Barreau*, 1952, **12**, 277.
(8) C. W. Jenks, *Int. Comp. Law Quart.*, 1956, **5**, 99.
(9) O. Schachter, *J.B.I.S.*, 1952, **11**, 14.
(10) O. Schachter, "Across the Space Frontier." Edited by C. Ryan, p. 118. **1952**: New York (Viking Press) **1953**: London (Sidgwick & Jackson).
(11) W. Heinrich, Prince of Hanover, Thesis, Univ. Goettingen, **1953**, p. 59.
(12) T. von Karman, "Aerodynamic Heating: The Temperature Barrier in Aeronautics." Paper presented to Univ. California, **1956**.
(13) *U.S.*, **271**, 609, 619; *L. Ed.*, **70**, 1112; *S. Ct.*, 1926, **46**, 592.
(14) B. N. Cardozo, "Paradoxes of Legal Science," p. 63, **1928**: New York (Columbia University Press); "Nature of the Judicial Process," p. 150. **1925**: New Haven (Yale University Press); quoted by B. W. Palmer, *Amer. Bar Assoc. J.*, 1948, **34**, 887.
(15) S. Goldman (Edited by), "The Words of Justice Brandeis," p. 63. **1953**: New York (Schuman).
(16) J. T. Loughran, *Fordham Law Rev.*, 1953, **22**, 1.
(17) *U.S.*, **285**, 393, 407, 408; *L. Ed.*, **76**, 815; *S. Ct.*, 1932, **52**, 443.
(18) O. W. Holmes, *Harv. Law Rev.*, 1897, **10**, 469.
(19) J. Dewey, *Cornell Law Quart.*, 1924, **10**, 17, 26, 27.
(20) *U.S.*, **347**, 590, 603; *L. Ed.*, **98**, 1015; *S. Ct.*, 1953, **74**, 826.
(21) *U.S.*, **333**, 103; *L. Ed.*, **92**, 568; *S. Ct.*, 1948, **68**, 431.
(22) D. D. Eisenhower, *U.S. Dept. State Bull.*, 21 Jan., 1957, p. 89.
(23) H. C. Lodge, *U.S. Dept. State Bull.*, 11 Feb., 1957, p. 225.
(24) ——, *Bull. Atomic Scientists*, 1957, **13**, 91.

# B.I.S. NEWS

## Space Medicine Symposium

Another important astronautical symposium is being organized by the Society; as previously announced, it will be concerned with space medicine and physiology. Several such conferences have been held in America from time to time, but this is the first in Great Britain. It is being held with the co-operation of the Royal Air Force Institute of Aviation Medicine.

The symposium is to take place in the Great Hall, B.M.A. House, Tavistock Square, London, W.C.1, on Thursday and Friday, 16–17 October, 1958 (the dates originally fixed have been altered for the convenience of those visitors from abroad who will also be attending the AGARD Aeromedical Panel in Copenhagen a few days later). The subjects to be discussed will include the effects of conditions likely to be encountered in space (excessive acceleration, weightlessness, radiation, temperature extremes, etc.) and means for their mitigation, food supplies, psychology, current research programmes, etc. In addition to the lectures (which will be followed by discussion periods), films of research work will be shown and there will be a small exhibition. The lectures will be delivered in two morning and two afternoon sessions.

Papers at present scheduled for presentation include:

*The Man-Machine System in Space Vehicles*, by Cmdr. George Hoover (U.S. Office of Naval Research).

*Round-Table Discussion.* Following Cmdr. Hoover's paper, the following members of the U.S. Office of Naval Research team will discuss their work: Capt. Sidney S. Sherby (Director, Naval Sciences Division, ONR), Dr. H. E. Sheets (Electric Boat Co. Division of General Dynamics Corp.), A. Mayo (Douglas Aircraft Co.), Owen Q. Niehaus (Bell Helicopter Corp.).

*Vision and Orientation at Extreme Altitudes*, by Squadron-Leader T. C. D. Whiteside (R.A.F. Institute of Aviation Medicine).

*Man's Thermal Environment during Interplanetary Flight*, by Flight-Lieutenant J. Billingham (R.A.F. Institute of Aviation Medicine).

*Heat Exchange between Man and His Environment on the Surface of the Moon*, by Flight-Lieutenant J. Billingham (R.A.F. Institute of Aviation Medicine).

*Impairment of Human Performance in Control*, by K. F. Jackson (R.A.F. Institute of Aviation Medicine).

*Effects of Prolonged Exposure to Positive g Loadings on the Pulmonary Gas Exchange*, by Dr. Hilding Bjurstedt (Laboratory of Aviation and Naval Medicine, Stockholm).

*Some Consequences of Weightlessness and Artificial Weight*, by Dr. M. P. Landsberg (National Aeromedical Centre, Soesterberg, Netherlands).

*Concentrated Food Supplies for Use in Space Vehicles*, by F. W. S. Hanson (Ministry of Agriculture, Fisheries and Food).

Several other papers are expected. Preprints of the principal papers will be provided to all Symposium participants, who will be charged a Conference Fee of four pounds. This will also cover the provision of light refreshments during the morning and afternoon sessions. A limited number of medical students will be admitted to the lectures at a reduced fee. Special application must be made to the Secretary. A few volunteers prepared to act as stewards at one or more sessions of the Symposium are required.

Arrangements are also being made for the provision of meals and hotel accommodation for Symposium participants who require them.

Further information relating to the Symposium may be obtained from—The Secretary, British Interplanetary Society, 12, Bessborough Gardens, London, S.W.1.

In view of the limited accommodation, members of the Society who wish to attend the Symposium are advised to apply to the Secretary without delay.

### Twenty-fifth Anniversary Celebrations Dinner

As part of the celebrations of the twenty-fifth anniversary of the founding of the Society, a dinner is being held at the Waldorf Hotel, Aldwych, London, W.C.2, on 17 October, 1958, at 7.30 p.m. for 8 p.m. The date has been chosen so that the event can also serve as a climax to the space medicine symposium, and a number of distinguished guests are being invited to attend. Evening dress is optional.

Tickets for the dinner are available on application to the Secretary with remittance (2 guineas, including gratuities). The dinner is open to members and their guests, whether or not they are able to attend the symposium. Accommodation is limited to 200.

Similar celebrations are being organized in the various Branches of the Society, and details may be obtained by writing to the Branch Secretaries.

### Branch Secretaries

On behalf of the Society, the Council wishes to express its thanks for their past services to Mr. P. W. Stone and Mr. L. S. Strickson, who have just resigned their offices as Secretaries of the Western and Yorkshire Branches, respectively. Mr. Strickson is shortly moving to London.

Mr. G. L. Garthwaite (The Little George Inn, New Road, Chippenham, Wiltshire) has been appointed Secretary of the Western Branch, and Mr. M. C. Greenwood (107, Bayswater Mount, Harehills, Leeds) Secretary of the Yorkshire Branch.

### London Lecture Programme, 1958-59

A number of illustrated posters advertising the Society's lectures to be held during the forthcoming session are being printed. Members who have opportunities for displaying these on the notice boards of their works, college or offices, etc., may obtain them on applying to the Secretary.

## Election of Members

The following elections were made at the Council Meeting on 1 February, 1958:

*Fellows.*

JAMES LEONARD ANDERSON, Apt. C-2-8, 5, Delano Place, Delano Court Apartments, Toronto, Ontario, Canada.
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The following elections were made at the Council Meeting on 1 March, 1958:

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# OTHER NEWS

## Sociedade Interplanetária Brasileira: Conselho Científico

The Sociedade Interplanetária Brasileira has established a Scientific Council to assist it in its work. The Council is intended to be international in character, and the Councillors already appointed include Walter Dornberger (U.S.A.), Andrew G. Haley (U.S.A.), Professor Mario Schenberg (Brazil), G. V. E. Thompson (Great Britain), Professor Gabriel Tikhov (U.S.S.R.), Wernher von Braun (U.S.A.).

## Earth Satellite Guide

Sylvania International Corp., a division of Sylvania Electric Products Inc., is issuing an Earth Satellite Guide, a pocket chart listing the mean radius, altitude and velocity corresponding to periods of from 1 hr. 25 min. to 24 hr. The chart is being distributed from the company's stand at the Brussels World Fair.

# ABSTRACTS

Edited by J. HUMPHRIES and J. FOLEY

A list of abbreviations of titles of journals was included with the 1954 index and addenda have been published in subsequent issues of the *Journal*. A further addendum is given below:

*Sci. Uses Earth Sats.* Scientific Uses of Earth Satellites. Ed. Van Allen. Pub. Chapman & Hall, 1956.

## AERODYNAMICS

(323) **The application of the shock tube to the study of the problems of hypersonic flight.** A. Hertzberg. *Jet Propulsion*, **26,** 549–54, 568 (*July*, 1956). Review of conditions in shock tubes and their uses. Conventional shock tube is limited to Mach 3 but in the Cornell shock tunnel employing a tube terminating in an expansion nozzle Mach numbers of over 10 can be obtained. Heat transfer techniques and a technique for the study of high-temperature chemical reaction rates are discussed. (18 *refs.*)

(324) **Application of hydraulic analog method to one-dimensional transient heat flow.** E. L. Knuth and E. L. Kumm. *Jet Propulsion*, **26,** 649–54, 659 (*Aug.*, 1956). An analogy is derived which is applicable to aerodynamic heating. The design of the analog computer is described and results given for the re-entry of nose-cones into the atmosphere. (6 *refs.*)

(325) **A simple method for computing the temperature history of a body entering the atmosphere at high supersonic velocities.** G. Oakes. *Jet Propulsion*, **26,** 888–91 (*Oct.*, 1956). Can be applied to any assigned values of prescribed initial conditions, such as altitude, velocity and path angle. (7 *refs.*)

## ASTRONAUTICS

(*See also* abstracts nos. 371, 372, 373 and 416.)

(326) **Flight in space.** V. Matović. *Vasiona*, **1** (1, 2), 16–19, 48–51 (*July-Sept., Oct.-Dec.*, 1953). (*In Serbo-Croat.*) Historical; escape from the Earth; transfer orbits; von Braun's Marsprojekt; interstellar flight.

(327) **Problem of overcoming terrestrial gravity in flight from the Earth.** T. P. Andjelić. *Vasiona*, **2** (3–4), 65–70 (*July-Dec.*, 1954). (*In Serbo-Croat.*) Elementary mathematics of escape from the Earth.

(328) **Fundamental problems of interplanetary navigation.** P. M. Djurković. *Vasiona*, **2** (3–4), 93–95 (*July-Dec.*, 1954). (*In Serbo-Croat.*) Transfer orbits, effect of inclination of planetary orbits to the ecliptic, etc.

(329) **Reason for the Fifth Congress of the International Astronautical Federation.** K. Sivčev. *Vasiona*, **2** (3–4), 70–82 (*July-Dec.*, 1954). (*In Serbo-Croat.*) Historical. Origin of the IAF, previous congresses, report of proceedings of the Fifth Congress at Innsbruck (1954).

(330) **Interstellar flight.** V. Matović. *Vasiona*, **3** (1), 1–3 (*Jan.-March*, 1955). (*In Serbo-Croat.*) Summary of paper by L. R. Shepherd, *J.B.I.S.*, **11**, 149–167 (1952).

(331) **The orbit of a small Earth satellite.** R. J. Davis, F. L. Whipple and J. B. Zirker. *Sci. Uses Earth Sats.*, pp. 1–22. Considers the motion of a small artificial satellite launched into an inclined moderately eccentric orbit from a point approximately 500 km. above sea level. Effects on the desired initial orbit produced by small deviations from launching conditions; perturbations produced by Earth's oblateness, atmospheric drag, action of Sun and Moon, variations of upper atmosphere density with time and latitude, Bernoulli forces acting on spinning object, upper atmosphere winds (including westerly wind caused by Earth's rotation).

(332) **Systems design considerations for satellite instrumentation.** L. G. deBey. *Sci. Uses Earth Sats.*, pp. 49–54. Discusses types of observation required for different artificial satellite programmes and proposes minimum array of instrumentation systems considered necessary.

(333) **Meteoric bombardment.** M. Dubin. *Sci. Uses Earth Sats.*, pp. 292–300. Method of measuring the influx of meteoric particles by detecting the acoustical energy generated upon impact. Results from V2 and Aerobee firings.

(334) **Insolation of the upper atmosphere and of a satellite.** P. R. Gast. *Sci. Uses Earth Sats.*, pp. 73–84. Estimates the ranges of max. and min. temperatures for satellites of various characteristics (surface absorptivity, shape, mass, specific heat) in various orbits.

(335) **Possibility of visual tracking of a satellite.** D. E. Hudson. *Sci. Uses Earth Sats.*, pp. 39–43. Suggests that a flash visible to the naked eye could be provided in an artificial satellite by a 400 candle-sec. xenon discharge tube and 8 lb. of batteries and condensers; a weaker source for telescope tracking would weigh about 1 lb.

(336) **Experiments for measuring temperature, meteor penetration, and surface erosion of a satellite vehicle.** H. E. LaGow. *Sci. Uses Earth Sats.*, pp. 68–72. Hypothetical environmental conditions are outlined. Proposed experiments involve (i) three thermistors—one internal, one at equator and one at pole of satellite, (ii) measurement of leak rate of satellite or counting with microphone, and (iii) measurement of change in electrical resistance of two elements formed on exterior of satellite.

(337) **Satellite tracking by electronic optical instrumentation.** H. J. Merrill. *Sci. Uses Earth Sats.*, pp. 29–38. Principal problems in optical tracking of satellites are diminished contrast against the Sun-illuminated sky, the tracking acceleration component and the concomitant instrument jitter. Possible improvements resulting from use of electronically-controlled optical instrumentation are considered.

(338) **Interpretations of observed perturbations on a minimal Earth satellite.** J. L. Sedwick, Jnr. *Sci. Uses Earth Sats.*, pp. 44–48. Method for calculating air resistance and the Earth's oblateness from observations of the orbit.

(339) **Visibility from a satellite at high altitudes.** V. J. Stakutis and J. X. Brennan. *Sci. Uses Earth Sats.*, pp. 137–146. Suggests extension of balloon-borne measurements of the sky's and Earth's luminances to satellite altitudes, and discusses suitable instrumentation.

(340) **Components for instrumentation of satellites.** H. K. Ziegler. *Sci. Uses Earth Sats.*, pp. 55–67. Environmental conditions during launching and in orbit; protective measures necessary; present and predictable availability of suitable components; comparison of power sources, electron devices, etc.

(341) **Time available for the optical observation of an Earth Satellite.** J. B. Zirker, F. L. Whipple and R. J. Davis. *Sci. Uses Earth Sats.*, pp. 23–28. Computations for specularly reflecting and diffusely reflecting 20-in. diameter spheres show that the former is visible over a larger fraction of the path. The time available for its observation has been calculated for several cases, taking sky brightness, geometry and the Earth's shadow into account.

(342) **Transfer between circular orbits.** D. F. Lawden. *Jet Propulsion*, **26**, 555–8 (*July*, 1956). A solution is given to the problem of transferring a rocket from a circular orbit about one planet into another about a second planet with minimum expenditure of fuel. The planetary orbits are assumed to be coplanar and the longitudes of the planets in their orbits at the instants of departure and arrival of the rocket are supposed to be specified. The case of transfer between the Earth and Mars is taken as a numerical example. (6 *refs.*)

(343) **Some problems of rocket development.** G. A. Partel. *Weltraumfahrt* (3) 72–6 (*Aug.*, 1956). (*In German*). Brief review of satellite dynamics, propellent performance, suitable geographical locations for satellite launching and launching of satellites from aircraft. (8 *refs.*)

(344) **The scientific value of artificial satellites.** F. L. Whipple. *J. Franklin Inst.*, **262**, 95–109 (*Aug.*, 1956). A popular résumé of the papers presented at the symposium "Earth satellites as research vehicles" on April 18, 1956, and published as *Monograph No.* 2 (*June*, 1956).

(345) **What the future holds for the Earth satellite.** R. P. Haviland. *G.-E. Rev.*, 10–15 (*Sept.*, 1956). Basic principles of launching with details of celestial mechanics, trajectories and orbits, mapping and geodesy, weather charting and forecasting, and wireless communications.

(346) **The potential energy of a small rigid body in the gravitational field of an oblate spheroid.** R. E. Robertson and D. Tatistcheff. *J. Franklin Inst.*, **262**, 209–14 (*Sept.*, 1956).

(347) **"Have you read any good books lately?"** A. V. Cleaver. *Spaceflight*, **1**, 40–2 (*Oct.*, 1956). An introduction to 45 books on spaceflight and related topics.

(348) **The Vanguard project.** K. W. Gatland. *Spaceflight*, **1**, 15–28 (*Oct.*, 1956). Historical survey of instrument carrying satellite designs with full details of Vanguard. (20 *refs.*)

(349) **Flight into space.** W. N. Neat. *Spaceflight*, **1**, 4–6 (*Oct.*, 1956). Review of basic principles.

## ASTRONOMY

(*See also* abstract no. 333.)

(350) **The Moon: our first neighbour in space.** *Vasiona*, **1** (1), 5–10 (*July-Sept.* 1953). (*In Serbo-Croat.*) General description of the Moon and its motion.

(351) **A satellite experiment to determine the distribution of hydrogen in space.** T. A. Chubb, H. Friedman and J. Kupperian. *Sci. Uses Earth Sats.*, pp. 152–156. Proposal involves simultaneous measurement of the intensity of hydrogen Lyman *alpha* radiation received directly from the Sun, and the resonance radiation of the same wavelength produced by sunlit hydrogen atoms in space.

(352) **The radiative heat transfer of planet Earth.** J. I. F. King. *Sci. Uses Earth Sats.*, pp. 133–136. Method for obtaining the vertical temperature distribution of a planetary atmosphere from the law of darkening of the planet's emission spectrum. Brief mention of a lightweight, rugged instrument developed by J. Strong of John Hopkins University and suitable for satellite use.

(353) **Measurements of interplanetary dust.** S. F. Singer. *Sci. Uses Earth Sats.*, pp. 301–316. Dynamics of charged interplanetary dust particles in the vicinity of the Earth, including diurnal effects, magnetic storm effects, etc. Application to possible rocket and satellite experiments.

(354) **Which properties of the Earth's atmosphere dare we also attribute to the atmosphere of Mars?** H. Faust. *Weltraumfahrt* (3), 65–8 (*Aug.*, 1956). (*In German.*)

## ATMOSPHERE

(*See also* abstract no. 338.)

(355) **Rockets in meteorology.** D. Vukmirovidj. *Vasiona*, **1** (2), 41–46 (*Oct.-Dec.*, 1953). (*In Serbo-Croat.*) Deals mainly with U.S. upper atmosphere research.

(356) **Ionospheric structure as determined by a minimal artificial satellite.** W. W. Berning. *Sci. Uses Earth Sats.*, pp. 253–262. Simplified analytical theory for determining ionospheric electron densities from trajectory measurements on a minimal satellite containing only a radio beacon transmitting a continuous wave.

(357) **Temperature and electron-density measurements in the ionosphere by a Langmuir probe.** G. Hok, H. S. Sicinski and N. W. Spencer. *Sci. Uses Earth Sats.*, pp. 263–267. Adaption of techniques previously used in rocket experiments (to investigate the lower E-layer of the ionosphere); for a spherical, unstabilized satellite, use of four independent probes distributed at the corners of an inscribed tetrahedron is recommended.

(358) **Satellite drag and air-density measurements.** L. M. Jones and F. L. Bartman. *Sci. Uses Earth Sats.*, pp. 85–98. Discusses the problem of obtaining values of air density from drag measurements on satellites. Measurements would be greatly improved by incorporating an accelerometer in the satellite. Proposes use of a 5-lb., 5-ft. diameter inflated sphere in conjunction with an improved version of the transit-time accelerometer used in Michigan sphere-drop density experiments.

(359) **Study of fine structure and irregularities of the ionosphere with rockets and satellites.** W. Pfister. *Sci. Uses Earth Sats.*, pp. 283–291. Experiments proposed involve a combination of the pulse-delay experiment similar to the U.S.A.F. electron-density rocket experiment with a kind of drift-type experiment measuring the signal amplitude fluctuations at three closely-spaced receivers.

(360) **Pressure and density measurements through partial pressures of atmospheric components at minimum satellite altitudes.** H. S. Sicinski, N. W. Spencer and R. L. Boggess. *Sci. Uses Earth Sats.*, pp. 109–118. Possible instruments and their principles of operation are indicated.

(361) **On the determination of air density from a satellite.** L. Spitzer, Jnr. *Sci. Uses Earth Sats.*, pp. 99–108. Analyses orbital and orientation methods. Former gives great accuracy at perigee altitude, but fluctuations of perigee density with time may prevent accurate density determinations at much greater heights. If the centre of pressure of a satellite is far from its centre of mass, measurement of changes in orientation can be used to determine air densities less than probable value at 300-km. Various methods of determining orientation are outlined.

(362) **Meteorological measurements from a satellite vehicle.** W. G. Stroud and W. Nordberg. *Sci. Uses Earth Sats.*, pp. 119–132. Proposes scanning of Earth's surface by photocells carried in satellite; these albedo measurements would give information of cloud distribution, hurricanes, etc. Presents a specific instrumentation suitable for IGY satellites.

(363) **Exploring the atmosphere with a satellite-borne magnetometer.** E. H. Vestine. *Sci. Uses Earth Sats.*, pp. 198–214. Describes the various systems of electric currents flowing within or beyond the Earth's atmosphere that have been suggested for explaining known geomagnetic variations at ground level. Satellite measurements can be used to separate these effects and to investigate the spatial distribution of the Earth's main magnetic field. Effect of time fluctuations in other phenomena (ionospheric motions, cosmic rays, aurorae, etc.) are briefly considered. (30 *refs.*)

## BIOLOGY AND MEDICINE

(364) **Medical problems of space flight.** M. Janjić. *Vasiona*, **2** (1), 7–10 (*Jan.-March*, 1954). (*In Serbo-Croat.*)

(365) **The physiological problems of the microclimate.** J. W. D. Walker. *Rev. Asoc. Argent. Interplanet.*, **3** (10) 27–31 (*April-June*, 1956). (*In Spanish*). Maintenance of a respirable atmosphere in a spaceship cabin, temperature control, food supply and protection against radiation. (7 *refs.*)

(366) **Climatization of animal capsules during upper stratosphere balloon flights.** D. G. Simons and D. P. Parks. *Jet Propulsion*, **26**, 565–8 (*July*, 1956). Simple methods for supplying oxygen and removing carbon dioxide have been developed. Internal capsule temperatures have been maintained at very nearly room temperature on 24 hr. flights by providing adequate insulation to use animal heat at night, and by cooling the capsule with a water-can cooler during the day. (6 *refs.*)

(367) **Medical problems involved in orbital spaceflight.** H. Strughold. *Jet Propulsion*, **26**, 745–8, 756, 788 (*Sept.*, 1956). Deals with weightlessness, visual problems, physiological day-night cycling, human engineering of space cabin and decompression of cabin. (36 *refs.*)

(368) **The colours of Martian "vegetation."** A. E. Slater. *Spaceflight*, **1**, 35–9 (*Oct.*, 1956). A critical review of the various theories. (20 *refs.*)

## CHEMISTRY

(*See also* abstracts nos. 407 and 413.)

(369) **Investigation of effects of additives on storage properties of fuming nitric acids.** C. B. Feiler and G. Morrell. *NACA RM No. E52J16* (1952).

(370) **Properties of fuming nitric acid affecting its storage and use as a rocket propellant.** D. M. Mason. *Jet Propulsion*, **26**, 741–4, 756 (*Sept.*, 1956). Discusses problems of storage for several months at about 130° F. Processes causing trouble are corrosion of containers and decomposition of acid. Corrosion of aluminium alloy and 18/8 stainless steels can be markedly reduced by addition of hydrofluoric acid. Thermal decomposition eliminated by ensuring that acid contains 12–16 wt. per cent. $NO_2$ and 2–3½ wt. per cent. water. (29 *refs.*)

## MISCELLANEOUS

(371) **Selection of engineering training in the field of rockets, jet propulsion, and astronautics.** G. P. Sutton. *Jet Propulsion*, **26**, 801–3 (*Sept.*, 1956). Objectives of training, analysis of curriculum and choice of school.

(372) **Careers in astronautics.** A. V. Cleaver. *Spaceflight*, **1**, 30–2 (*Oct.*, 1956). A guide to employment in the missile and allied industries.

(373) **Tsiolkovskii—founder of astronautics.** G. V. E. Thompson. *Spaceflight*, **1**, 7–8 (*Oct.*, 1956). Biography.

## PHYSICS

(374) **Proposed measurement of solar stream protons.** W. H. Bennett. *Sci. Uses Earth Sats.*, pp. 194–197. Experiments with a laboratory tube termed the Störmertron, which produces scale models of proton orbits in the Earth's magnetic field, has indicated the existence of two types of orbit: "free" and "captive." The latter are believed to originate at about 100 km. altitude; a polar satellite experiment for detecting and measuring them in the auroral zones is outlined.

(375) **A Lyman *alpha* experiment for the Vanguard satellite.** T. A. Chubb, H. Friedman and J. Kupperian. *Sci. Uses Earth Sats.*, pp. 147–151. A satellite experiment offers the possibility of monitoring the Sun in Lyman *alpha* radiation almost continuously for many days; brief indication of equipment required.

(376) **Ultraviolet stellar magnitudes.** R. J. Davis. *Sci. Uses Earth Sats.*, pp. 157–165. A tentative map of the sky for a wavelength of 1249 Å has been constructed for use in selecting the most interesting regions for study when extraterrestrial photometry of high-resolution becomes possible from rockets or artificial satellites.

(377) **Satellite geomagnetic measurements.** J. P. Heppner. *Sci. Uses Earth Sats.*, pp. 234–246. Examines practical requirements and techniques for measuring the total scalar magnetic field from a satellite above the densely ionized regions of the upper atmosphere, to settle various questions connected with geomagnetic storms and other disturbances.

(378) **Quantitative intensity measurements in the extreme ultraviolet.** H. E. Hinteregger. *Sci. Uses Earth Sats.*, pp. 166–170. E.U.V. is the term used here to refer to electromagnetic radiation from about 1500 down to a few Ångströms in wavelength; rocket experiments have already provided evidence of E.U.V. radiation from the Sun, but its effect on satellite materials and measurements is unknown. Problems in satellite measurements of E.U.V. are discussed.

(379) **Geomagnetic information potentially available from a satellite.** L. Katz. *Sci. Uses Earth Sats.*, pp. 247–252. Satellite investigation of variations in atmospheric electric current systems and of the main magnetic field are discussed.

(380) **Measurements of the Earth's magnetic field from a satellite vehicle.** S. F. Singer. *Sci. Uses Earth Sats.*, pp. 215–233. Application of satellite observations to measurement of (*a*) the main field and its secular variations, (*b*) short-time variations of the field and atmospheric current systems, (*c*) transient variations produced by rapid motions of ionized gas near the Earth. (36 *refs.*)

(381) **Cosmic-ray observations in Earth satellites.** J. A. Van Allen. *Sci. Uses Earth Sats.*, pp. 171–187. Apparatus, choice of orbits, etc., for investigation of (*a*) geographical dependence and temporal variations of cosmic-ray intensity in the vicinity of the Earth, and (*b*) relative abundance of heavy nuclei in the primary cosmic radiation.

(382) **Study of the arrival of auroral radiations.** J. A. Van Allen. *Sci. Uses Earth Sats.*, pp. 188–193. Proposals for satellite (polar orbit) and rockoon investigations of soft radiation.

(383) **Experimental checking of the general theory of relativity with an artificial satellite of the Earth.** V. L. Ginsburg. *Priroda* (9), 30–9 (*Sept.*, 1956). (*In Russian.*)

## PROJECTILES

(*See also* abstracts nos. 402 and 420.)

(384) **The relative geometry and motion of a missile's flight path and the range geodesic on a spheroidal Earth.** L. M. Ranch. *Consolidated Vultee Aircr. Corp., Rept. No. FZA–089*, 65 pp. (*April* 18, 1955).

(385) **Improved on-off missile stabilization.** R. W. Bass. *Jet Propulsion*, **26**, 644–8, 643 (*Aug.*, 1956). A new synthesis procedure by means of which the delays due to time-lag and hysteresis in the system can be eliminated. Results applied to several specific control systems. (16 *refs.*)

(386) **Japanese guided missiles in World War II.** M. Caidin. *Jet Propulsion*, **26**, 691–4, 696 (*Aug.*, 1956). Descriptions of missiles in production or under development at the end of World War II.

(387) **French rockets and missiles.** *Jet Propulsion*, **26**, 804–5 (*Sept.*, 1956). A series of photographs.

(388) **Logistics of underground bases for rockets and guided missiles.** E. B.-Winandy. *Fusées*, **1**, 171–8 (*Oct.*, 1956). (*In French.*) (17 *refs.*)

## RADIO AND ELECTRONICS

(389) **Electrotechnology and spaceflight.** M. Milošević. *Vasiona*, **2** (2), 51–53 (*April-June*, 1954). (*In Serbo-Croat.*) Brief consideration of terrestrial and ship-carried electrical equipment for control, navigation, generation, etc.

(390) **Electromagnetic propagation studies with a satellite vehicle.** F. B. Daniels. *Sci. Uses Earth Sats.*, pp. 276–282. Proposals for determination of the integrated ion density for a vertical column by measurement of the rotation of the plane of polarization of radio signals from a satellite.

(391) **A satellite propagation experiment.** L. M. Hartman and R. P. Haviland. *Sci. Uses Earth Sats.*, pp. 268–275. Radio propagation experiment to obtain knowledge about the F2-layer of the ionosphere; satellite equipment consists of a low-power continuous-wave transmitter operating on a frequency near the ionospheric cut-off frequency corresponding to max. geometric line-of-sight distances from the satellite.

## ROCKET MOTORS

(*See also* abstract no. 387.)

(392) **Some aspects of guided missile power-plant reliability requirements.** H. A. Eubank, C. C. Ross and R. C. Stiff. *Aerojet-General Corp.*, 19 pp. (1955).

(393) **Approximate analysis of rocket nozzle scale and dynamic effects.** F. P. Durham. *Colorado Univ. Rept. No.* 5, 45 pp. (*Oct.*, 1954-*April*, 1955).

(394) **On jet separation in supersonic rocket nozzles. I. The characteristics of flow.** P. Eisenklam and D. Wilkie. *Imperial College of Science and Technology Rept. JRL-29*; *DGGW EMR/55/4* (*May*, 1955).

(395) **The performance characteristics of a small rocket-type nozzle.** F. P. Durham. *Colorado Univ., Engng. Exptl. Station, Summary Rept.* 6. 31 pp. (*June*, 1955).

(396) **Pressure measuring instrumentation for combustion stability studies.** L. Green. *Aerojet-General Corp. Tech. Note No.* 14, *U.S.A.F. Off. Sci. Res. TN* 55–474, 42 pp. (*Dec.*, 1955).

(397) **Investigation of rocket engines for the direct measurement of exhaust jet velocities.** L. E. Bollinger and R. Edse. *Wright Air Development Center Tech. Rept.* 54–269, 73 pp. (*March*, 1956).

(398) **Liquid propellent rocket motors.** R. V. Dyrgalla. *Rev. Asoc. Argent. Interplanet.*, **3** (10), 9–16 (*April-June*, 1956). (*In Spanish.*) Survey of applications.

(399) **Demonstration of reliability in liquid propellent rocket engines.** A. G. Thatcher and H. A. Barton. *Jet Propulsion*, **26**, 781–5 (*Sept.*, 1956). Discusses reliability programmes and statistical methods. (4 *refs.*)

(400) **Ideas behind the rocket.** D. Hurden. *Spaceflight*, **1**, 9–14 (*Oct.*, 1956). Basic principles of rocket propulsion with details of operation of liquid propellent rocket motors.

(401) **Regarding thermodynamic nuclear rockets.** I. Sänger-Bredt. *Fusées*, **1**, 111–3 (*Oct.*, 1956). (*In French.*) Shows that the use of low chamber pressures is advantageous. (3 *refs.*)

(402) **The effect of vehicle structure on propulsion system dynamics and stability.** R. S. Wick. *Jet Propulsion*, **26,** 878–87 (*Oct.*, 1956). The complete system is analysed by servomechanism techniques. Results of stability analysis for a monopropellent rocket motor are presented in terms of the natural frequency of the vehicle structure, the combusion lag and the distribution of mass. (13 *refs.*)

## ROCKET PROPELLENTS

(*See also* abstract no. 370.)

(403) **Interim report on an experimental study of combustion instability in solid propellent rocket motors.** L. Green, M. Lysow and K. L. Nall. *Aerojet-General Corp. TN*-11, *Air Force Off. Sci. Res. TN* 55–233, 165 pp. (*July*, 1955).

(404) **Steady state properties of a simplified model of solid propellent burning.** L. Green. *Aerojet-General Corp. TN*-12, *Air Force Off. Sci. Res. TN* 55–334, 22 pp. (*Sept.*, 1955).

(405) **Non-steady behaviour of a simplified model of solid propellent burning.** L. Green. *Aerojet-General Corp. TN*–15, 20 pp. (*Nov.*, 1955).

(406) **A microscopic examination of extruded double base propellents.** J. Quinlan. *Franford Arsenal, Rept. No. R*-1302, 18 pp. (*Dec.*, 1955).

(407) **Field methods for the determination of hydrazine and water in furfuryl alcohol-aniline rocket fuel mixtures.** R. F. Muraca, S. P. Vango and L. L. Taylor. *Calif. Inst. Tech., Jet Prop. Lab. Progr. Rept. No.* 20–284, 7 pp. (*Feb.*, 1956).

(408) **Method for determining the tensile properties of solid rocket propellents. I. Nitrocellulose base propellents.** Joint Army-Navy-Air Force Panel on Physical Properties of Solid Propellants. *Solid Propellant Information Agency SPIA/PP*8, 56 pp. (*March*, 1956).

(409) **Studies on the reaction stability of solid propellent charges.** L. Green. *Aerojet-General Corp. Rept.* 1077, *Air Force Off. Sci. Res. TN* 56–10, 78 pp. (*March*, 1956).

(410) **Theoretical performance of JP-4 fuel and liquid oxygen as a rocket propellent. I. Frozen composition.** V. N. Huff and A. Fortini. *NACA RM E56A*27, 35 pp. (*April*, 1956).

(411) **Rapid estimation of specific impulse of solid propellents.** A. O. Dekker. *Jet Propulsion*, **26,** 572–4 (*July*, 1956). For a propellent which forms only gases the specific impulse can be found within 2 per cent. in 15 min. given only empirical formula and heat of formation. Works only for flame temperatures $\geqslant 2000°$ K, negligible dissociation and fuel-rich mixtures. (6 *refs.*)

(412) **A short review of nuclear propellents for rockets.** G Partel. *Alata* (133), 25–6 (*July*, 1956). (*In Italian.*)

(413) **Calculation of a Mollier diagram for the decomposition products of aqueous hydrogen peroxide solutions of 90 weight per cent. $H_2O_2$ content.** J. G. Tschinkel. *Jet Propulsion*, **26,** 569–71, 575 (*July*, 1956). Pressure range covered is 0·1 to 100 kg./cm$^2$. (6 *refs.*)

(414) **Observations on the irregular reaction of solid propellent charges.** L. Green. *Jet Propulsion*, **26,** 655–9 *Aug.*, 1956). Experimental evidence that high frequency pressure oscillations of finite amplitude can prevail in the charge cavity during outwardly stable operation and qualitative explanation. (18 *refs.*)

(415) **The design of cylindrical propellent grains.** L. I. Epstein. *Jet Propulsion*, **26,** 756–9 (*Sept.*, 1956). Discusses general mathematics of design and describes a method for designing a grain in which the burning surface area is a prescribed function of the portion of the web thickness burned through. (3 *refs.*)

(416) **Solid propellents in spaceships.** W. Proell. *J. Space Flight*, **8** (7), 1–5 (*Sept.*, 1956). Review of uses as boosters, main propulsion and auxiliaries. (4 *refs.*)

(417) **General thermodynamics of propellents.** P. Magot-Cuvru. *Fusées*, **1,** 115–28 (*Oct.*, 1956). (*In French.*) Method of calculating entropy/enthalpy diagrams.

(418) **The theoretical specific thrust of a rocket motor for the C-H-N-O-F system.** M. S. Morgan, J. Silverman and W. T. Webber. *Jet Propulsion*, **26,** 874–7, 891 (*Oct.*, 1956). Curves of theoretical specific thrust based on isentropic expansion of frozen equilibrium gases are given versus temperature for various hypothetical conditions and heats of formation at a chamber pressure of 500 p.s.i.a. and nozzle outlet pressure of 15 p.s.i.a.

These can be used for real propellent combinations by interpolation. Accuracy is ±1 per cent. (2 *refs.*)

### ROCKET PROPULSION

(*See also* abstract no. 347.)

(419) **Redstone Arsenal: Army Ordnance center for guided missiles.** H. N. Toftoy. *Sperryscope*, **14** (2), 2–5 (1956).

(420) **Rockets, costs.** T. M. Tabanera. *Rev. Asoc. Argent. Interplanet.* **3** (10), 17–25 (*April-June*, 1956). (*In Spanish.*) Review of research costs and basic data on a number of rockets. (5 *refs.*)

(421) **Ten years of Project Squid—a bibliography.** *Jet Propulsion*, **26**, 660–80, 688 (*Aug.*, 1956). Abstracts of 244 papers covering all aspects of jet propulsion. The papers are classified under properties of materials, physical processes, chemical processes, combustion phenomena, engines and propulsive systems and instrumentation.

(422) **Jets—review of literature.** M. Z. v. Krzywoblocki. *Jet Propulsion*, **26**, 760–779 (*Sept.*, 1956). Deals with the fundamentals and mathematical theory of free boundary flow and jet; with the distribution of velocity, density, pressure and temperature in laminar jets; transport of mass, momentum and energy in turbulent jets; and with closely related phenomena.

## REVIEWS

**Scientific Uses of Earth Satellites.** Edited by James A. Van Allen. 10 × 2½ in. Pp. x + 316, illustrated. 1956. Ann Arbor: University of Michigan Press. ($10.00.) London: Chapman and Hall, Ltd. (£3 3s.)

This book describes "the best current (*i.e.*, before 1956) thinking of leading scientists, technicians, and military experts on the ways in which the man-made satellites, to be launched during the International Geophysical Year 1957, may contribute to our knowledge of the Universe," to quote from the cover. The book is entirely an American production, and it is therefore fortunate for the authors and publishers that it is easier to write about artificial satellites than it is to put them up, otherwise a large part of this publication would have been out of date by now. As it is, the publishers' prognostication about the evanescent nature of the text has turned out to be pessimistic and the book is still of considerable interest.

The book is a collection of thirty-three papers describing some of the experiments it is hoped to make with the American artificial satellites, together with a certain amount of theory which is of general application. Because of the large number of topics dealt with, and the varying degrees of clarity of the different authors, it is impossible to make any generalizations about the book except to say that the fairly high standard of the mathematics makes this a book for the specialist rather than the layman.

Chapter 1 deals with the orbits of satellites, and the effects of small deviations of the launching conditions upon the orbit. Then the effects of atmospheric drag and the oblateness of the Earth are considered. Various atmospheric models are used to investigate the possible theories of atmospheric drag. The mathematics is rather concise, and the appendix to the chapter defines 52 different symbols which are used in 20 pages of text. The next chapter deals with optical observations of satellites, and it is shown that for a satellite circling 200 miles above the Earth's equator, an observer on the equator would have a maximum observation time of about 160 seconds. Chapter 3 continues this topic, and describes the use of electronic apparatus in conjunction with optical equipment to improve the accuracy and sensitivity obtained by optical equipment alone. There are some useful data here about satellite magnitudes and photographic exposure times. Chapter 4 deals with a proposal to make visible tracking of a satellite possible at night by building-in a flashing light. It is shown that this could be done with 8 lb. of equipment. Chapter 5 is short but highly mathematical, and describes how the oblateness of the spheroidal Earth can be calculated from the satellite orbit perturbations.

Chapters 6 and 7 make easy reading, and deal in a descriptive manner with satellite instrumentation. Some details are given about solar power devices.

Chapter 8 deals very briefly with the measurement of temperature and surface erosion of satellites. The next chapter is very interesting, and describes the calculations of the equilibrium temperatures of bodies in space under various conditions of illumination and absorption. It is shown that the problem may well be one of supplying heat to a satellite rather than having to keep it cool, otherwise the battery temperatures may become too low for efficient working. Chapters 10, 11 and 12 all deal with the measurement of atmospheric

pressures and densities at various altitudes. Some experimental results already obtained by dropping inflated Nylon spheres from Aerobees, are given, and the proposal of putting accelerometers in rigid spheres is discussed in detail. The authors consider that it should be possible to measure atmospheric densities as low as $10^{-16}$ g./cm$^3$ (Chapter 11).

Chapter 13 deals with meteorological observations and the necessary instrumentation, whilst Chapter 14 is a short mathematical discussion of the radiative heat transfer of the Earth.

Chapter 15 considers the probable visibility from a high-altitude satellite. The next chapter deals with the measurement of the Lyman alpha line in the $H_2$ spectrum, which is required for the study of the chromosphere. This line cannot normally be measured because it is absorbed by the atmosphere of the Earth. Its importance lies in the fact that it is believed to be the radiation responsible for radio fade-outs during solar flares. Chapter 17 describes how the Lyman line can be used to determine the distribution of hydrogen in space.

The next five chapters all concern various proposals connected with the radiations in space. Ultra-violet, cosmic, auroral, and solar stream proton radiations are discussed. The various measurements which should be taken, and the methods of interpreting the results, are described in detail.

Chapter 23 stresses the importance of geomagnetic observations from satellites containing magnetometers, which can be used to investigate atmospheric currents. The measurement of the Earth's magnetic field is discussed in the next three chapters, and it is described how such observations would help in the investigation of magnetic storms.

Chapter 27 deals with the measurement of ionospheric structure using a minimal satellite, which need only contain a continuous transmitter beacon; electron density measurements could be obtained from the satellite trajectory. The simplified theory of the method is given. Similar measurements using a probe are described in the next chapter. The following three chapters discuss various observations it is proposed to make using radio waves propagated from a satellite. This method can be used to investigate V.H.F. fading, the distribution of atmospheric ions and the detailed electronic structure of the atmosphere.

Finally, the last two chapters are concerned with proposals for the satellite investigation of meteoric bombardment and measurements of interplanetary dust. The first of these chapters (32) describes the use of an ultrasonic meteor bombardment detector. Some results of the use of this technique are now available, and it appears that the method is unreliable, the results being incompatible with those of other types of observations, probably because of the stray ultrasonic noise which seems to be generated in the equipment. The final chapter mentions various measurements which should be made in connection with the motion of charged interplanetary dust particles, assuming that the dust is charged, which fact has not been verified.

The experiments suggested in this book are extremely ingenious, and only time will tell to what extent they are all possible or relevant. The value of the book, however, lies not so much in the details of the proposed experiments, but in the ideas behind these, and in the theories and factual data given. Whatever the fate of the proposals, this portion of the text will remain valid, and for this reason the book is recommended, although it is only fair to say that buying it is a rather expensive method of obtaining the parts most people will want (some of which have been published elsewhere). Potential purchasers are also reminded that the mathematical background required to understand some of the theoretical work is rather high. The references given at the ends of the chapters total 233, of which all but about 48 are American.

N. H. Langton.

**The Handbook of Rockets and Guided Missiles.** By Norman J. Bowman. 8½ × 5½ in. Pp. 328, with 170 illustrations. 1957. Whiting, Indiana: Perastadion Press, Box 607. ($6.50.)

Anyone who has ever attempted to compile data tables of rockets and missiles will appreciate some of the difficulties the author of this volume must have faced in preparing what is undoubtedly the most comprehensive collection of references that has yet appeared in public print.

Not that the book is devoted entirely to data. The first 71 pages contain definitions of jet-engines (turbo-jet and ram-jet), rocket engines (solid and liquid), guidance systems (command, beam-rider, homing, etc.), and American missile service designations, as well as much other relevant information, including a survey of the various applications of rockets and missiles: surface-to-air, surface-to-surface, air-to-surface, and so on. Also appearing

in this section are rocket-powered aircraft, balloons and rockets for upper air research, and a survey of "foreign" missiles. Under the latter heading the author includes restrained comment on Soviet missile developments, much of which appears to have been backed up by the physical appearance of Russian rockets in the Parade through Red Square on 7 November last, commemorating the 40th anniversary of the Bolshevik Revolution. Although there is some speculation (*e.g.*, on the nature of Russian underwater-launched missiles), Mr. Bowman is seldom, if ever, dogmatic, which is in welcome contrast to accounts appearing in certain American magazines interesting themselves in missiles and rockets, which frequently descend to the level of fiction in purporting to describe Soviet achievements in this field.

A reasonably acurate appraisal of Russia's first artificial satellite, for example, appears on page 63 of Mr. Bowman's book:

> "Professor Kapitza is in charge of the project and has stated that it will be launched in 1957. The gross weight is estimated at 75 tons. It will be a three-step rocket and all steps are said to be in an advanced test stage. Recently, Professor Pokrovsky stated that the satellite itself would be from 20 to 24 in. in diameter and would weigh close to 100 lb. The orbital distance has been variously reported between 185 and 800 miles minimum distance. The Russians are considering launching their satellite on a polar orbit. . . ."

Mr. Bowman has compiled his tables from no less than 1,276 independent sources, mainly books and magazines, and has arranged them in alphabetical order with no distinction between rockets, missiles, engines, or the firms that produce them. Flicking through the pages, one finds, for example: A3—German experimental rocket developed at Peenemünde . . .; BMW—Abbreviation for Bayrische Motoren Werke; Congreve rockets—British rockets used widely about 1815 . . .; Cook—A research company which makes the Skokie and Cherokee drop-test missiles . . . ; Thor IRBM—This is a missile of projected 1,500 miles range being developed for USAF by Douglas Aircraft Company. . . . Each reference is, of course, backed up with as much numerical data and information as the author can find. Altogether, the alphabetical method of classification works well and one is saved the bother of a separate index.

It would be remarkable if the book did not contain some errors, for so much unofficial data is presented in American magazines entirely without qualification that all too often such references are totally unreliable. Indeed, it is extremely difficult for the discriminating person (as Mr. Bowman obviously is!) to sort out the wheat from the chaff, and the situation is not helped by the reticence of government departments to release official figures. Several of the errors noted, not directly attributable to this source, are of a minor nature:

Page 72. A1—this German experimental rocket was not "developed at Peenemünde about 1933," but at the Kummersdorf Army Proving Grounds; the centre at Peenemünde was not completed until 1937.

Page 174. RAVEN—described as a British solid-fuel upper atmosphere research rocket with wrap around boosters, which has achieved a ceiling of 120 miles. Actually, Raven is the name of the solid-propellent motor for the Gassiot upper-atmosphere research rocket (named Skylark), a single-stage vehicle without boosters of any kind, at least in its present form. It has not achieved 120 miles altitude.

Page 211. Vanguard, Step I. The fuel is given as a mixture of 95 per cent. gasoline, 4 per cent. alcohol and 1 per cent. silicone oil, whereas, in fact, kerosine is employed. This, however, is excusable as the book was compiled before the change to kerosine was made by the manufacturer, which illustrates how rapidly a reference book of this kind is liable to become "dated." Indeed, such is the pace of rocket development these days that authors (faced with a time lag of some six months before publication) can scarcely hope to bring out a "topical" book.

In view of this difficulty, the book is not typeset but is (expertly) typewritten and reproduced by a lithographic offset process on good quality paper, which makes production and subsequent revision much less expensive. However, something that might be improved in later editions is the section of 166 line drawings of rockets and missiles which concludes the book; many of these are badly proportioned and rather crudely drawn. To some extent, this is the fault of the method of reproduction which does not lend itself to good draughtsmanship.

Although by British standards this is an expensive volume (it retails here at 35s.), it is on the whole, a valuable record which should find a place wherever rockets and guided-missiles are schemed, built or debated.

KENNETH W. GATLAND.

**Izotopy w Służbie Człowieka.** By Olgierd Wołczek. 19 × 12.5 cm. Pp. 346, with 165 illustrations. 1956. Warszawa: Państowe Wydawnictwo Naukowe. (Zł. 8.10.)

"Isotopes in the Service of Man" is the title of the book, but this subject is dealt with only in Part III. Part I introduces the reader to the modern theory of the structure of matter, showing its evolution from the ideas current at the end of the eighteenth century to the present-day concepts of the structure of the nucleus and its relation to such phenomena as the existence of isotopes and nuclear fission. Part II (pp. 93–238) is concerned in a more detailed way with the nature of isotopes (radioisotopes in particular) and with their technology.

The book is "popular" enough to be of interest to anybody with only a basic knowledge of physics and chemistry, but on the other hand it is not so "popular" as to be of no interest to the scientist of degree standard, who whilst not directly concerned with this particular branch of science wishes to obtain a general view of the subject. In a relatively small space but without undue simplification it provides admirably a glance into this vast field. The story of the applications of isotopes in medicine, agriculture, science and industry is enlivened by practical examples, which to some readers may be completely novel. More space is provided for a discussion of the peaceful uses of nuclear energy with its possibilities of being a major source of power in the not-so-distant future. The book concludes with a short description of the application of nuclear power to rocket propulsion for interplanetary travel.

R. S. Bem.

**Wschodza Nowe Ksiezyce (O sztucznych satelitach Ziemi).** By Władysław Geisler. 20·5 × 14·5 cm. Pp. 189, with 49 illustrations. 1957. Warszawa: Wiedza Powszechna. (Zł. 10.—.)

There is hardly another subject that could claim such world-wide popular interest as the problems of space travel, and artificial Earth satellites in particular. Because of this, there was a need in Poland for a book which concisely and in not too technically detailed a manner could explain what the subject is about. "New Moons Are Rising" is just such a book. It is divided into five chapters, of which the first gives basic information about the solar system. This is followed by others on the principles of the motion of artificial satellites, their characteristics, the reasons for their construction, and a discussion on their present state of development and the trends of future work, leading ultimately to interplanetary travel.

Out of necessity, most of the text is based on western literature, because, as the author himself admits, Russian accounts are still very scarce. Some information about Russian sputniks 1 and 2 is, however, included. It is surprising that in such a small space so full an account of this fascinating subject could be given and it is the reviewer's opinion that after reading this book the previously uninitiated could intelligently listen to any discussion on artificial Earth satellites and interplanetary travel.

J. E. Stolarczyk.

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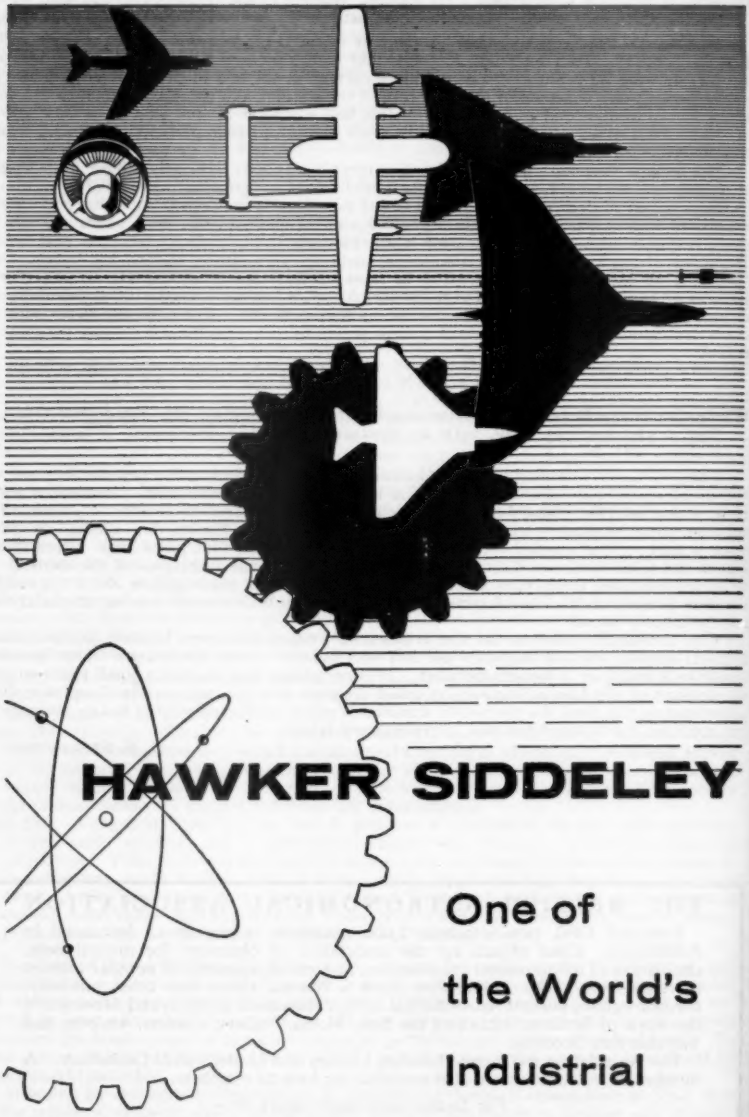


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